SAND80-7 140
Unlimited Release
March 198 1

STRATEGIC PETROLEUM RESERVE (SPR) GEOLOGICAL SITE CHARACTERIZATION REPORT BAYOU CHOCTAW SALT DOME

Section I Bayou Choctaw Cavern Stability Issues,
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Section II Geological Site Characterization, Bayou Choctaw Salt Dome,
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Section III Salt Properties for Bayou Choctaw Dome,
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INTRODUCTION

SPR Program Description

The Energy Policy and Conservation Act (EPCA) enacted in December 1975 provided the legislative authorization for the Strategic Petroleum Reserve (SPR). The objective of the SPR is to store substantial quantities of crude oil in order to diminish US vulnerability to the effects of a severe interruption in supply. The current plan for the SPR consists of three phases that, when complete, will provide the US with a 750-million-barrel (MMB) reserve. The legislation authorized up to a l-billion-barrel reserve, but plans have not been completed for the last 250 MMB.

The Phase 1 portion of the reserve uses existing storage volume at five sites. Four of the sites (Bryan Mound, TX; West Hackberry, LA; Sulphur Mines, LA; and Bayou Choctaw, LA) have solution-mined caverns that were originally created to produce brine as chemical feedstock, and the fifth site, Weeks Island, LA, has a conventional salt mine. The total existing capacity of these five sites is 248 MMB. Phase 2 plans are to expand the Bryan Mound and West iiackberry sites by solution-mining 12 and 16 additional caverns, respectively, of 10 MMB each. Plans for the remainder of the storage capacity to reach to 750 MMB reserve are under review by the US Department of Energy (DOE).

Sandia SPR Participation

Sandia National Laboratories at DOE request has made a short-term systems integration and engineering support study. The results of this study have been published.[1] Several geotechnical recommendations resulted from this study, and Sandia was assigned the responsibility to provide a coordinated program of geotechnical investigations to support continued development of the SPR. The geotechnical program will provide a sufficiently comprehensive, site-specific data base to support the planning, design, construction, and operation of SPR crude-oil storage facilities. These data will be used in assessing the long-term stability of SPR storage caverns and mines to minimize the potential for cavity failures that could result in significant environmental impacts, economic losses, or failure to withdraw oil when needed. A long-term monitoring plan will be developed that will assure maintenance of the quantity and quality of the stored crude oil in a readily recoverable condition. The geotechnical program includes the following activities: geological site characterization; engineering design assistance and evaluation, including numerical simulation studies; laboratory and bench-scale testing of salt cores from SPR sites; monitoring and interpretation of field events; and instrumentation evaluation and development. These efforts pertain to tne five sites currently in the SPR program.

During the contract period for the Bayou Choctaw. geological site characterization, the SPR Project Manager's Office (SPRPMO) asked Sandia to participate in two additional studies. The first was the site location for Expansion Cavern 102 (this work was done by Acres American, Inc.), and the second was the stabilization of Cavern 4. The site for Cavern 102 has been selected and work is in progress, but the study of Cavern 4 continues at the time of this writing.

Report description

Section I reviews cavern stability, integrity, and usability for both existing and planned caverns at Bayou Choctaw. The early analyses were done by using typical material properties. Future analyses will be done by using the information reported in Sections II and III of this report. As these analyses are completed, results and recommendations will be published for the existing and. planned caverns.

Section II of this report is a comprehensive geological site characterization study done by Acres American, Inc. for Sandia. The geological characterization was to be in two phases. The first phase, a comprehensive study, would be prepared from existing data, and in the second phase field programs would be used to gather specific information as needed. Section II represents the results of Phase 1 only. We do not believe a Phase 2 geological field program is necessary to support development and operation of Caverns 15, 18, and 19 or the construction of Expansion Cavern 102. The edge of the dome and the quality of the salt must be better defined before Cavern 20 can be fully used for oil storage.

Section III of this report on salt properties of the Bayou Choctaw salt dome is necessarily brief. No geophysical logs exist that provide salt properties, and the only available core (from Well 19A) is being analyzed by Sandia materials groups. Results will be added in Section III as they become available.

Sandia Recommendations Resulting From the Geological Site Characterization Studv

Cavern 15. We recommend continued operation of this cavern to the Allied Chemical Corporation agreement, and no freshwater withdrawal cycles until Cavern 17 is bought by the government and a 15/17 gallery is planned.

Cavern 18. No recommendation.

Cavern 19. No recommendation.

Cavern 20. Because of the proximity of this cavern to the edge of dome and the uncertainty of this distance, we recommend an exploratory program to accurately define the edge and the quality of salt between the cavern and the edge before oil storage. These data would allow a determination of the long-term suitability of this cavern for oil storage. If oil storage is required before such a program, we recommend: (1) a thorough test of the cavern, including a low-pressure test to determine the current condition of the cavern, (2) if at all possible, limitation of oil storage to that above -4050-ft level, and (3) continuous monitoring of cavern pressure to immediately detect any change that could result from communication between the cavern and the exterior of the dome.

SECTION I

BAYOU CHOCTAW CAVERN STABILITY ISSUES

OCTOBER 1980

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ABSTRACT

Cavern stability, integrity, and usability issues regarding existing and planned storage caverns in the Bayou Choctaw salt dome are reviewed. Previous studies are discussed, ongoing investigations are summarized, and data needed to support the assessments are described.

SECTION I

CONTENTS

Page

ILLUSTRATIONS

Figure

Introduction and Summary

The US Strategic Petroleum Reserve (SPR) program is currently storing crude oil in Caverns 15, 18, and 19 at the Bayou Choctaw site, and Cavern 20 is being prepared to receive crude oil. Expansion Cavern 102, formerly called Location C, has been surveyed and preparations for drilling and leaching have begun. This report briefly discusses the four caverns mentioned and also a potential subsidence problem at Cavern 4, which is on DOE property but is not suitable for oil storage. Other caverns owned by the DOE have been judged unacceptable for oil storage because they (1) are not pressure-tight, (2) communicate hydraulically with each other, or (3) have thin roofs and are thus structurally questionable.

There are many common issues of concern at each site--depressurization effects, long-term creep closure, etc. The techniques used to address concerns at one site apply at all sites.

A review of cavern stability issues for each SPR site was provided in Reference 1 in 1979. From this blueprint for action, Sandia National Laboratories began a program of geotechnical investigations to support the continued development of the SPR. Initial evaluations of cavern integrity have been based upon the use of generic or "typical" salt properties. These evaluations have attempted to bound concerns associated with creep-closure rates, depressurization of the caverns to zero surface pressure on the oil column, and pillar or web thickness. Concurrently with these evaluations, a materials testing program was begun to characterize the salt from each site. These data will be used in current and future studies to more accurately represent the geomechanical response of existing caverns in the Bayou Choctaw dome and to simulate the additional cavern planned for the dome. Additional data on the failure or fracture of the salt will also provide cavern-specific geological input to leaching-simulation activities. Initial evaluations of cavern integrity were based upon cavern spacing data and dome boundary locations of questionable accuracy. Site characterization activities (Section II) have now brought together more consistent geological and geometrical data on sediments, cap rock, salt stock, and cavern locations that will be valuable in assessing stability concerns.

Site characterizations, and careful consideration of the numerical analyses made to date on dayou Choctaw caverns and caverns in other domes, have resulted not only in several useful observations about the existing caverns but have also helped define additional evaluations that are needed.

In their present configurations, Bayou Choctaw Caverns 18 and 19 currently used for storage of crude oil are geomechanically stable and can be safely operated as storage caverns. Cavern 15 should be operated to the current agreement with Allied Chemical Corporation and should be cycled with saturated brine during withdrawal. Since Cavern 20 is ~130 ft from the edge of the salt dome, we cannot recommend its use until the distance from the cavern to the edge of the dome and the quality of the salt are known.

Existing Caverns at Bayou Choctaw

Table 1 summarizes the geomechanical data for SPR Caverns 15, 18, 19, and 20 in the Bayou Choctaw salt dome. In addition, brief paragraph descriptions, a map, and sonar surveys of the caverns are found in Chapter 6 of Geological Site Characterizat?on of the Bayou Choctaw Salt Dome; by Acres American, Inc. Since the Acres site characterization is bound in this volume as Section III, the information in Chapter 6, "Salt Stock Gf-?ol~~v,~' ~:i?l mr:t* be repeated in this section, which deals primarily with geomechanC% TX~~~.

Because the cavern geometry (as related to the vertical and horizont' distances to the dome boundaries and to adjacent caverns) largely governs its suitability for storage from a geomechanics viewpoint, these properties and ensuing ratios to the cavern diameter, D, have been recorded in Table 1. The parameters for the Bayou Choctaw caverns (Table 1) are seen as the bounds on several of the parameters in the overall program.

The distance between adjacent caverns, P, is the current wall thickness (not the center-to-center spacing between caverns) and is used as a measure of the likelihood for cavern coalescence. The P/D ratio indicates the pillar width relative to the cavity size and inversely relates to the intensity of the loading that might be felt in the pillar; i.e., a 100-ft pillar between 500-ft-dia caverns (P/D = 0.2) would be more intensively loaded than if the surrounding caverns at the same depth had only a diameter of 100 ft (P/D = 1).

lhe roof or back thickness, B (amount of salt between cavern roof and the cap rock), is important to cavern stability since the salt must be thick enough to ensure proper grouting of the casing. The B/D ratio indicates the thickness-to-span ratio for the cavern roof. As the B/D ratio decreases to well below 1.0, concern intensifies regarding how adequate the roof materia is for transmitting loads from the cap rock to the cavern walls without developing tensile stresses.

Another parameter, E, that can limit the suitability of an existing cavern for the storage of crude oil is how near the caverns are to the edge of the dome. The salt near the edge of a dome is more likely to be locally fractured and to contain impurities than the salt in the interior of the dome. Any linkage between geologic formations bordering a dome and caverns within the dome must be avoided since the product stored in a cavern could conceivably be lost. Proximity of caverns to the edge of the dome may therefore limit the number of withdrawal cycles of a cavern.

Bayou Choctaw Cavern 15

Because DOE Cavern 15 is estimated to be 100 to 200 ft from Allied Chemical Company's Cavern 17, both are discussed in this section. Cavern 15, a stable configuration of 16.6 MMB, currently contains 8 MMB of crude oil. Cavern 17 is likewise a stable configuration of 12.2 MMB and is used by Allied Chemical Company to store ethane. The ethane pressure is described by the following equation:

$$P_{17}\ (\mathrm{psi}) = (0.16)\ (\mathrm{depth\ in\ ft}) + 1250$$

In 1979 we ran a two-dimensional, vertical, plane-strain, elastic-plastic analysis of the web between the two caverns, using a minimum estimated web thickness of 100 ft. The analysis showed a small region of tensile stress in the web area between the two caverns inside contour line I (Figure 1). This condition existed when Cavern 15 was held at oil-head pressure and Cavern 17 at ethane pressure, in accordance with the above equation.

Our analysts considered this a very conservative solution. Therefore, in 1980 a three-dimensional, elastic-plastic analysis was made by using the same web thickness and pressure conditions of the two-dimensional analysis. For both the two- and three-dimensional analyses a lithostatic loading of 1 psi/ft was simulated on a symmetric half section of the caverns (Figure 2). Cavern 15 is on the left in Figure 2. Figure 3 shows a vertical (Z) stress on a plane through the centerlines of both caverns. Unlike the two-dimensional analysis, no tensile stress appears in the web from this model. We believe this is the most representative answer. Figure 4 shows the horizontal (X) stress in a plane perpendicular to the cavern axes; no tensile stress appears in the web. Figure 5, perhaps the most interesting, shows the maximum stress in the plane of Figure 4. Again, there is no area of tensile stress in the web, and the value shown closest to tension is 985 psi in compression. Based upon the more valid three-dimensional analysis, we believe that the 100-ft web under the pressure conditions given provides structural adequacy for SPR use.

Bayou Choctaw Cavern 18

According to a 1978 sonar survey, Cavern 18 is a tall, candle-shaped cavern extending from 2100 to -4200 ft, with diameters varying from-60 ft at the top to 300 ft at the bottom. This cavern should be very stable since the distance to cap rock, edge of dome, or other caverns is more than adequate. The shape is quite regular, with no salt ledges or other anomalies indicated on the sonar survey.

Bayou Choctaw Cavern 19

Cavern 19 is an ideally shaped cavern extending from 3000 to 4200 ft in depth with an average diameter of -200 ft. It is well-separated from other caverns and the edge of the dome. The shape is very regular, with no ledges or other anomalies. Nothing in the history of this cavern or in its geometry causes us to doubt its structural integrity.

Bayou Choctaw Cavern 20

A two-dimensional, plane-strain, elastic-plastic analysis was made of Cavern 20 to determine minimum edge-of-dome thickness. The parameters used in this analysis were oil-pressure head on the cavern, a 100-ft-thick cavern web at the edge of the dome, and lithostatic pressure on the exterior of the salt dome. The horizontal, plane-strain slice was assumed at a maximum cavern depth of 4305 ft and a maximum cavern diameter of 500 ft. Figure 6 shows the finite-element mesh picture of the geometry analyzed. Figure 7 shows a plot of the maximum tensile stresses produced in the area most likely to exhibit such stresses. No tensile stress developed, indicating that a competent salt web 100 ft thick is adequate to withstand cavern depressurization to oil-head pressure. However, competent salt would mean an inclusion-free zone (see Section II, paragraph 6.3.4), and that is very difficult to guarantee without an experimental program.

Bayou Choctaw Expansion Cavern 102

Four potential cavern locations have been proposed in an earlier study[2] and have been described in detail by Acres American, Inc., in Chapter 6 of their Geological Site Characterization of the Bayou Choctaw Salt Dome (see Section II of this volume). Figures 6-14, 6-31, and 6-32 in the Acres SK-tion show both the locations and radial sections through the proposed caverns to the edge of the salt dome. Location A was judged unacceptable, Locations B and D potentially acceptable if additional geophysical work supports that view, and Location C was judged acceptable.

Our investigation of expansion cavern locations A, B, C, and D raised concerns about Cavern 4. Cavern 4 was abandoned by Allied Chemical Company ~25 years ago as a brine cavern. The cavern now extends -30 ft into the 120-ft-thick massive gypsum-anhydrite cap rock. Many similarities are observed between former Cavern 7 (now Cavern Lake) and Cavern 4. Aerospace Corporation has been asked by the DOE to assess the risks of Cavern 4 for SPK operations at the site. Sandia has been asked to consider ways of stabilizing Cavern 4 in an attempt to preclude a repetition of what happened at Cavern 7. Both Aerospace and Sandia are continuing their activities at this time, and nothing further can be said of the subject in this paper.

References

1. Systems Integration and Engineering Support Study for the Strategic Petroleum Reserve (SPR) Program - Final Report, SAND79-0637 (Albuquerque, NM: Sandia National Laboratories, June 1979).

2. Jacobs/D'Appolonia architectural engineering firms, New Orleans office, "Surge Cavern Feasibility Study," R010, January 1980.

EQUATION OF STATE

1. INTRODUCTION

Temperature, pressure and density data, collected from routine well operations, can be used to accurately define the physical and mechanical properties of the subsurface materials. These three variables are a function of site specific depth, geohydrology and geologic features.

Data compiled in the course of the Bayou Choctaw Geologic Site Characterization has been compiled for the purpose of understanding the behavior of the salt and the surrounding sediments.

We believe that a total understanding of these variables and how they relate to site specific conditions can result in the development of an "Equation of State" which subsequently may be utilized in assessing alternate methods for creating and expanding caverns, resulting in a more cost effective program.

The following sections briefly present the data collected during the study.

2. PRESSURE

Pressures measured in the earth are related to the weight of the rock column. The State of Louisiana requires that the tubing pressures be recorded for all oil and gas wells. This is the surface. flowing pressure during production. By knowing the size of the pipe, the flow rate, fluid density, and well depth, the actual fluid pressure in the rock can be calculated. This calculated pressure generally agress with the shut-in bottom hole pressure obtained from drill-stem tests. The oil or gas pressure is in equilibrium with the groundwater head in the sand at the oil-water contact. Thus, the thicker the producing sand, the greater the hydrocarbon pressure as a function of depth. Pressure data from wells at Bayou Choctaw, as converted to static rock conditions are plotted in Figure 1 and listed in Table 1.

The principal oil production zone or trend is marked on Figure 1. The data clusters in the Pliocene at 2,500 feet, Miocene production at 3,000 to 6,000 feet and deeper Oliogocene gas-condensate production. No production is above the 1,600-foot depth in the fresh water zone. The cluster of points in the middle of the Miocene (between 5,000 and 5,500 feet depth) represents oil production from the main producing zone, the No. 8 Sand, the thickest oil sand (over 200 feet thick) at Bayou Choctaw. The pressure in this zone is relatively high due to the thick oil column. The Oliogocene production (below 7,500.foot depth) is gassy being sealed by thick overpressured Anahuac shale.

The brine pressure (increasing with salinity and depth) forms the limit for oil and gas production on the right (Figure 1).

The left hand line on the Figure is the pressure of the column of gas-cut oil, as calculated from mean gas-oil ratio (Figure 2). The weight of the salt overhang on the west side of the dome has resulted in an over saturated condition with gas greater than the oil saturation line as related to oil density (Figure 3).

3. TEMPERATURE

In order to show the effect salt structures have on the geothermal temperature gradients, two graphs were constructed (Figure 4). The first graph plots the temperatures measured in the wells in the immediate vicinity of the dome (including those which penetrated salt), and second plots temperatures in regional wells.

The wide variance in temperatures at equal depths, as noted on the two graphs, is the result of temperature measuring techniques. To achieve a more accurate temperature profile, a well must be left idle for several days (twice the drilling time for shallow holes) after drilling so that the temperatures of the drilling fluid can equilibrate with the surrounding sediments. Because of the high cost of drilling, this procedure is not always followed. Therefore, those temperatures that plot to the left (cooler) are likely from holes that were not equilibrated.

As shown in Figure 4, those wells which either penetrated or are close to the salt edge tend to have higher temperatures than those further away. The average geothermal gradient from ground surface to approximately 8,000 feet is approximately 7oF per 1,000 feet. Below 8,000 feet, the gradient steepens to approximately 11^{o}F per 1,000 feet in the surrounding sediment, and to approximately 300F per 1,000 feet in the salt. This change in gradient occurs at the major lithologic change from the Miocene sands to the underlying Oligocene shales.

The more permeable Miocene sands tend to dissipate heat more rapidly by circulating groundwater than the more impermeable shales. Therefore, the shales and the salt retain more heat resulting in a higher geothermal gradient. The gradients of these rocks are related to their material properties and thermal conductivity.

The regional data supports this finding. The regional data plotted on Figure 4 north of the site in the Bayou Choctaw Northwest, Port Hudson and False River fields. The temperature gradients from these wells are the same as shown in Figure 4A, with the exception that the change in gradient occurs 5,000 feet deeper at a depth of about 13,000 feet. As stated above, this depth corresponds to the contact between the Miocene sands and Oligocene shales. The contact is higher at the dome as a result of salt dome tectonics which has dragged this contact upwards along the dome boundaries.

Examination of Figure 4B shows the Amoco Production Company (AP) wells to have a higher temperature gradient than the deeper Chevron (CH and CO) wells. The Amoco wells are in the Port Hudson field which, based on seismic data, is structurally controlled by a salt ridge. The sediments in the Port Hudson field being closer to the salt have a higher gradient than those in the Chevron wells at the False River field which is stratigraphically controlled.

In summary, the geothermal gradients in and around salt domes are controlled by the surrounding geology and geohydrology. A comprehensive understanding of the site geology and geothermal gradients allows for a quantification of the salt behavior. At depths below 8,000 feet, the temperature in the Bayou Choctaw salt increases rapidly with depth, due to shale insulation.

4. DENSITY

The density of salt (2.2 g/cm^3) is essentially independent of depth. Sediment density, however, increases with depth due to compaction and reduction in porosity under burial load. This is shown on Figure 5 which is a plot of density versus depth as obtained from the well logs. As can be seen, sand and shale are of equal density at 3,000-foot depth and sand and salt are of equal density at approximately 8,000 feet. The regional density-depth curve (Figure 5) follows the well-known Athy reference curve for shale. The curves converge at approximately 35,000 feet near the melting point of silicates (density 2.6 to 2.7 g/cm^3).

In addition, there is an increase in density due to salt stress (Figure 6), as porosity is reduced at the salt edge by the dynamic stress of salt movements.

5. APPLICATION TO CAVERN STORAGE

Reduction and plotting of available well data on and around existing and proposed storage facilities allows for a detailed definition of the salt and the surrounding sediment's physical, mechanical, and thermal properties.

Several applications of this data to cavern storage may be considered. Existing storage facilities have been principally developed by the time consuming and, frequently costly, leaching method. Because of the creep properties of the salt, this method has generally been restricted to the upper 5,000 feet.

One possible alternative to the leaching method would be to develop caverns at greater depths (5,000 to 10,000 feet) be utilizing high pressure to cause the salt to creep "outwards" forming a cavern. At any site-specific depth and temperature, the creep rates will increase with pressure differential. If the pressure is too great, the salt may fracture resulting in communication to the edge of the dome. Therefore, it is important to accurately define the site-specific condition as they relate to temperature, density and pressure.

Preliminary assessment of the pressure creep method for cavern formation shows that the concept is a potentially viable alternative to leaching. However, additional work remains to be done to define the methods, costs, equipment and time to perform such work.

TABLE 1
BAYOU CHOCTAW SPR SITE
WELL PRESSURE DATA

WELL IDENTIFICATION		DEPTH (ft)		PRESSURE	GAS-OIL RATIO	
Township 8 South, Range 11 East						
Section 28						
Levert Heirs						
BA 1	Temple Hargrove et al	7937	TP	1125#	864	Oil .
BA B-1	British American Oil Production Co.	9414	TP	725%	2,326	Oil
BA C-l		9524-50	TP	1000#	310	Oil
		9476-95	TP	1350#	615	Oil
BE 2	Brock Exploration Corp.	9171		NA	(Est) 700	Gas
Morley Cypress Co.						
BA 1	Temple Hargrove	NA			994	Oil
BA 2		8023	TP	1125#	264	Oil
BA 3		7837	TP	1300#	600	Oil
BA 4		8064	TP	1240#	758	Oil
BA 5		8240	TP	2850#	100,000	Gas
BA 6	British American Oil Production Co.	6916-29	SITP	2535#	NA	Gas
BA 8		5233 .	TP	780#	477	Oil
BA B-1		9308	TP	1180#	885	Oil
C 2	Carter Oil Co.	8470	TP	900#	NA	Oil
C 3		8214	TP	17501	650	Oil
Section 29						
Morley Cypress Co.						
C 1	Standard Oil of Louisiana	8206	TP	900#	NA	Oil
E. B. Schwing						
BA 1	Temple Hargrove et al	7772	TP	2500#	2,698	Oil
BA A-2		8482	TP	8401	456	Oil
BA A-3		9071	TP	3000#	8,000	Oil
BE 1	Brock Exploration Corp.	8693	TP	200#	850	Oil
BE 4		7214	TP	12758	875	Oil
			SITP	4120#	---	Oil
LC 2	Louisiana Oil Crusaders	8014	TP	1230#	NA	Oil
LC 4		8470	TP	16001	NA	Gas
LC 6		8220	CP	800#	NA	Oil
Township 9 South, Range 11 East						
Section 52						
Gay Union Corporation						
C 9	Standard Oil of Louisiana	5470	TP	300#	200	Oil
C 10	Carter Oil Company	6902	TP	200#	NA	Oil
C 11		8460	TP	1480#	619	Oil
C 13		8278	TP	2600#	NA Dry	Gas
C 15		5335	TP	595#	400	Oil
C 16		8474	TP	40158	807	Oil
						Oil

TABLE 1 (Cont 'd)

WELL PRESSURE DATA

WELL IDENTIFICATION			DEPTH (ft)		PRESSURE	GAS-OIL RATIO	
C	18		7805	TP	1150#	200	Oil
C	19		7857	TP	7008	360	Oil
			8390	SIBHP	3750#	NA	Oil
C	21		8375-85	SIBHP	3950#		
			8241-56 & 8260-67	SIP	2130#		
			8071-75 & 8078-84	SIP	2680#		
			8022-36	SIBHP	2070#		
			7658-63	SIP	325#		
			7545-54 & 7565-72	SIP	2600#		
			7317-27	BHFP,	3100#		
			7288-96 & 7253-60	BHFP,	3175#		
C	22		794s	TP	11251	764	Oil
C	23		5502	TP	550#	234	Oil
C	24		7457	TP	1000%	435	Oil
C	25		7448	TP	1950#	77,333	Gas
C	27		7167	TP	740#	489	Oil
C	29		5530	TP	855#	1,684	Oil
C	30		7281	TP	10208	450	Oil
C			4548	TP	3008	469	Oil
C	3:		6446	TP	400#	386	Oil
C	34		5491	TP	650#	722	Oil
C	35		5544	TP	650#	767	Oil
C	37		5500	TP	515#	1,300	Oil
C	38		4142	TP	225#	712	Oil
C	40		7495	TP	1145#	1,461	Gas
C	41		4218	TP	340#	324	Oil
C	42		7185	TP	0-150#	NA	Oil
C	51	Texas Gas Exploration Corp. (Gay Mineral Corp.)	9579	TP	560#	609	Oil
Gulf	1	Gulf Refining Co.	7626	TP	975#	841	Oil
Wilberts Mineral Corporation							
F	1	Freeport Sulphur Co.	5425	TP	650#	NA	Oil
F	20	Freeport Oil Co.	4045	TP	4408	TLTM	Oil
f	22		4060	TP	4201	Low	Oil
F	23		5288	TP	410#	262	Oil
F	24		5510	TP	5808	369	Oil
F	26		5550	TP	450#	335	Oil
F	29		5320	TP	615#	33	Oil
F	31		5600	TP	675#	282	Oil
			5304	TP	665#	288	Oil
F	32		4298	TP	3006	189	Oil
F	33		5624-36	TP	500#	364	Oil
			5102-12	TP	610#	328	Oil
			5342	TP	385#	NA	Oil
F	35		5292-5312	TP	610#	256	Oil
			5150-5206	TP	6308	313	Oil
F	37		5488	TP	600#	226	Oil
			5463	TP	570#	230	Oil
F	38		5489	TP	515#	232	Oil
F	39		4064	TP	4308	332	Oil
F	40		3870	TP	315#	382	Oil
F	41		S286	TP	545#	. 414	Oil
			5164	TP	500#	373	Oil
F	42		4648	TP	465#	355	Oil

TABLE 1 (Cont'd)

WELL PRESSURE DATA

WELL IDENTIFICATION			DEPTH (ft)		PRESSURE	GAS-OIL RATIO	
F	43		5254-66	TP	500#	344	Oil
			5110-30	TP	600#	380	Oil
F	44		5190	TP	1475#	Nil	Oil
F	45		2732	TP	1708	Nil	Oil
F	46		2322	TP	140#	NA	Oil
F	47		2383	TP	135#	111	Oil
F	48		2182	TP	300#	Gas Lift	Oil
F	49		2000	TP	125#	Gas Lift	Oil
F	52		5180	TP	445#	428	Oil
F	54		2828	TP	235#	191	Oil
F	56		8168	TP	1125#	496	Oil
			7446	SITP	26508	NA	Gas
F	58		52S0	TP	280#	256	Oil
F	59		3322	TP	275#	297	Oil
F	71		2700	TP	340#	392	Oil
F	72		2349-80	TP	4428	NA	Oil
			2206-10	TP	215#	NA	Oil
F82			7816	TP	520#	NA	Oil
Wilbert's Myrtle Grove							
C	20	Carter Oil Co.	2868	TP	255#	114	Oil
C	21		2862	TP	235#	72	Oil
C	22-I		2856	TP	295#	NA	Oil
C	23		2884	TP	254#	100	Oil
C	2s		2623	TP	115#	64	Oil
C	26		2884	TP	290#	100	Oil
C	27		2842	TP	250#	61	Oil
	27A		2712	TP	275#	Nil	Oil
C	28		5254	TP	350#	371	Oil
C	31		3210	TP	150#	Nil	Oil
C	32		1642	TP	130#	Nil	Oil
C	33		3952	TP	4301	521	Oil
C	34		4610	TP	150#	Nil	Oil
C	36		5377	TP	620#	Low	Oil
C	37		4072	TP	365#	Low	Oil
C	39		5040	TP	475#	388	Oil
C	41 40		5270	TP	575#	325	Oil
			3404-10	TP	2908	Nil	Oil
			3804-10	TP	145#	Nil	Oil
C		Humble Oil & Refining	5141	TP	630#	542	Oil
C	42 43		5160	TP	560#	267	Oil
C	44	Texas Gas Exploration	4660	TP	510%	426	Oil
			4660	S1 BHP	2055#	426	Oil
H	1	T. M. Hoffman	2874	TP	180#	Nil	Oil
H	2		2601	TP	60#	Low	Oil
Wilbert's Myrtle Grove							
C	11	Standard Oil of Louisiana	4800	TP	275#	NA	Oil
C	13	Carter Oil Co.	3735	TP	300#	NA	Oil
C	16		7626	TP	1090#	765	Oil
Section 60							
Wilbert Mineral Corporation							
F	80	Freeport Oil Company	2714	TP	325-425#	216	Oil

TABLE 1 (Cont'd)

WELL PRESSURE DATA

WELL IDENTIFICATION			DEPTH (ft)		PRESSURE	GAS-OIL RATIO	
Section 61							
Wilbert Mineral Corporation							
F	34	Freeport Oil Co.	7790	TP	11501	505	Oil
F	36		7960	TP	1110#	4,126	Oil
F	57		8247-57 & 8270-78	TP	1040-1450#	1,008	Oil
			8056-82	TP	7408	782	Oil
F	63		8158	TP	4001	NA	Oil
			7984	TP	960#	340	Oil
F	77		7905	TP	11158	1,756	Oil
Gay Union Corporation							
C	45	Humble Oil & Refinery	10378	TP	1950#	942	Oil
C	46		10336	TP	1008	Nil	Oil
			10355	TP	195#	1,030	Oil
			10336	TP	250#	393	Oil
C	48		10098	TP	2950#	NA	Dry Gas
Section 53							
E.B. Schwing et al							
BA	B-l	Temple Hargrove et al	8635	TP	1300#	670	Oil
BA	B-2		8758	TP	8258	445	Oil
BA	B-3		8599	TP	730#	702	Oil
BA	B-4		8304	TP	1240#	662	Oil
BA	B-5		8398	TP	4601	423	Oil
BA	B-6		8268	TP	1080#	616	Oil
BA	B-7		8148	TP	11801	880	Oil
State	1	Temple Hargrove & Freeport Sulphur	8206	TP	13001	540	Oil
Wilbert Minerals Corporation							
F	2	Freeport Sulphur Co.	5460	TP	750#	NA	Oil
F	2		7937	TP	1450#	NA	Oil
F	4		7946	TP	1500#	1,675	Oil
f	5		7880	TP	1395#	606	Oil
F	6		8190	TP	1250#	615	Oil
F	7		8370	TP	1100#	601	Oil
F	98		8612	TP	1050#	568	Oil
			8396	TP	1100#	666	Oil
F	11		5310	TP	6308	318	Oil
F	12		2665	TP	250#	200	Oil
F	13		8130	TP	1350#	603	Oil
F	14		7842	TP	11508	667	Oil
F	15		8218	TP	8701	581	Oil
F	17		7834	TP	730#	754	Oil
F	18	Freeport Oil Co.	8202	TP	435#	466	Oil
F	19	(Wilbert State Unit)	8238	TP	910%	2,744	Oil
F	21		4140	TP	550#	564	Oil
F	2s		5510	TP	560#	288	Oil
F	28		4754	TP	150#	1,924	Oil
F	51		5474	TP	650#	417	Oil
	53		5558	TP	610#	394	Oil
F	55		3780	TP	275#	403	Oil
F	60		2751	TP	250#	Nil	Oil

TABLE 1 (Cont'd)

WELL PRESSURE DATA

WELL IDENTIFICATION			DEPTH (ft)		PRESSURE	GAS-OIL RATIO	
F	60		2751	TP	250#	Nil	Oil
F	61		2308	TP	7908	NA	(P&A)
F	62 64		4974	TP	420#	800	Oil
			8066	TP	500#	NA	Oil
f	65		8760	TP	1280#	704	Oil

Section 53

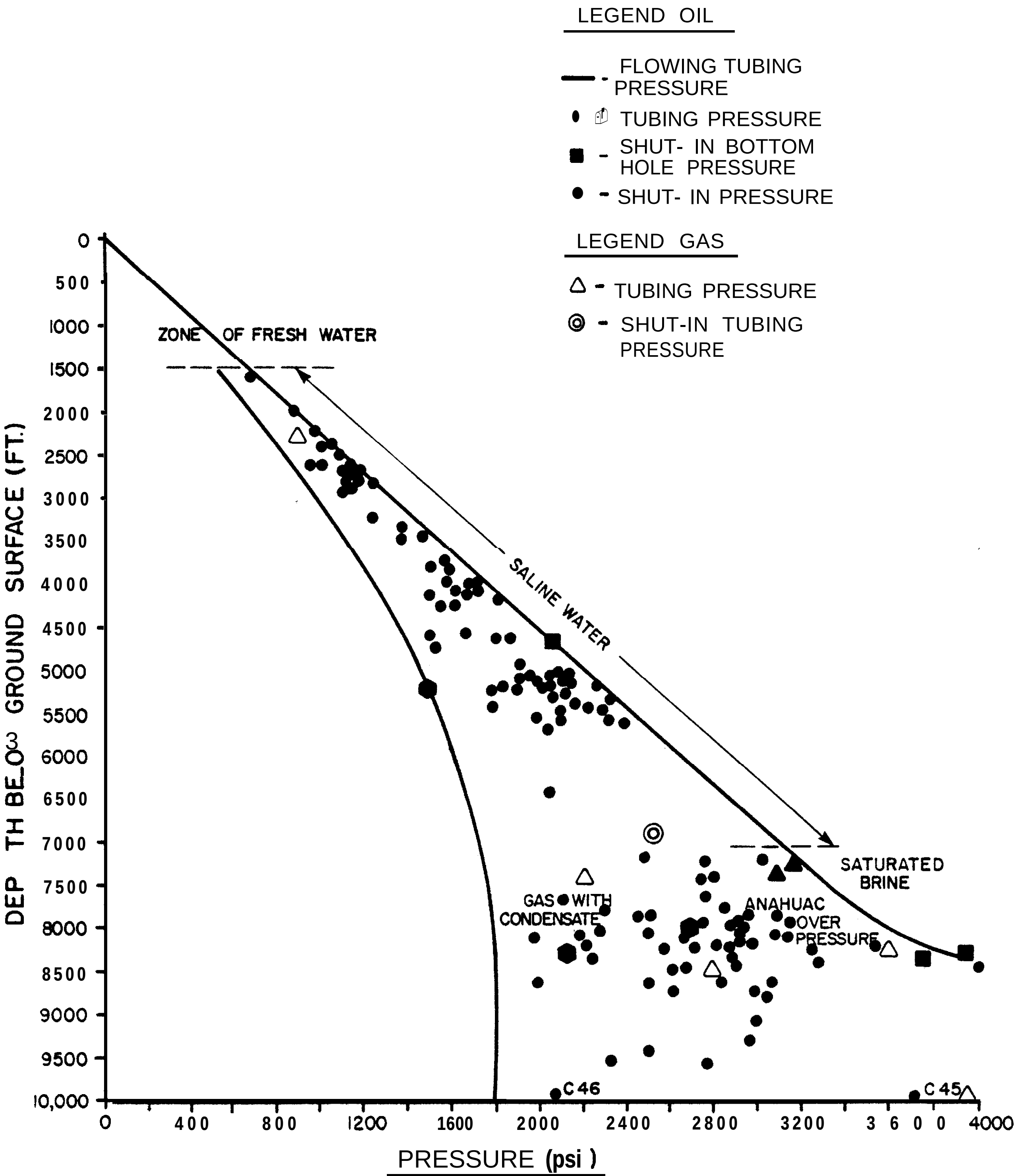
Wilbert Minerals Corp.

F	67	Freeport Oil Co.	2743	TP	220#	NA	Oil
F	68		2588	TP	400#	NA	Oil
F	69		2512	TP	170#	NA	Oil
F	70		2982	TP	4008	NA	Oil
F	73		4034	TP	440#	NA	Oil
F	74		2866	TP	250#	139	Oil
f	76		7302	TP	800#	333	Oil
F	78		8229	TP	180#	NA	Oil
F	81 79		5298	TP	8008	92	Oil
			8742	TP	112008	556	Oil

NOTES FOR TABLE A-4

1. # pressure in pounds per square inch.

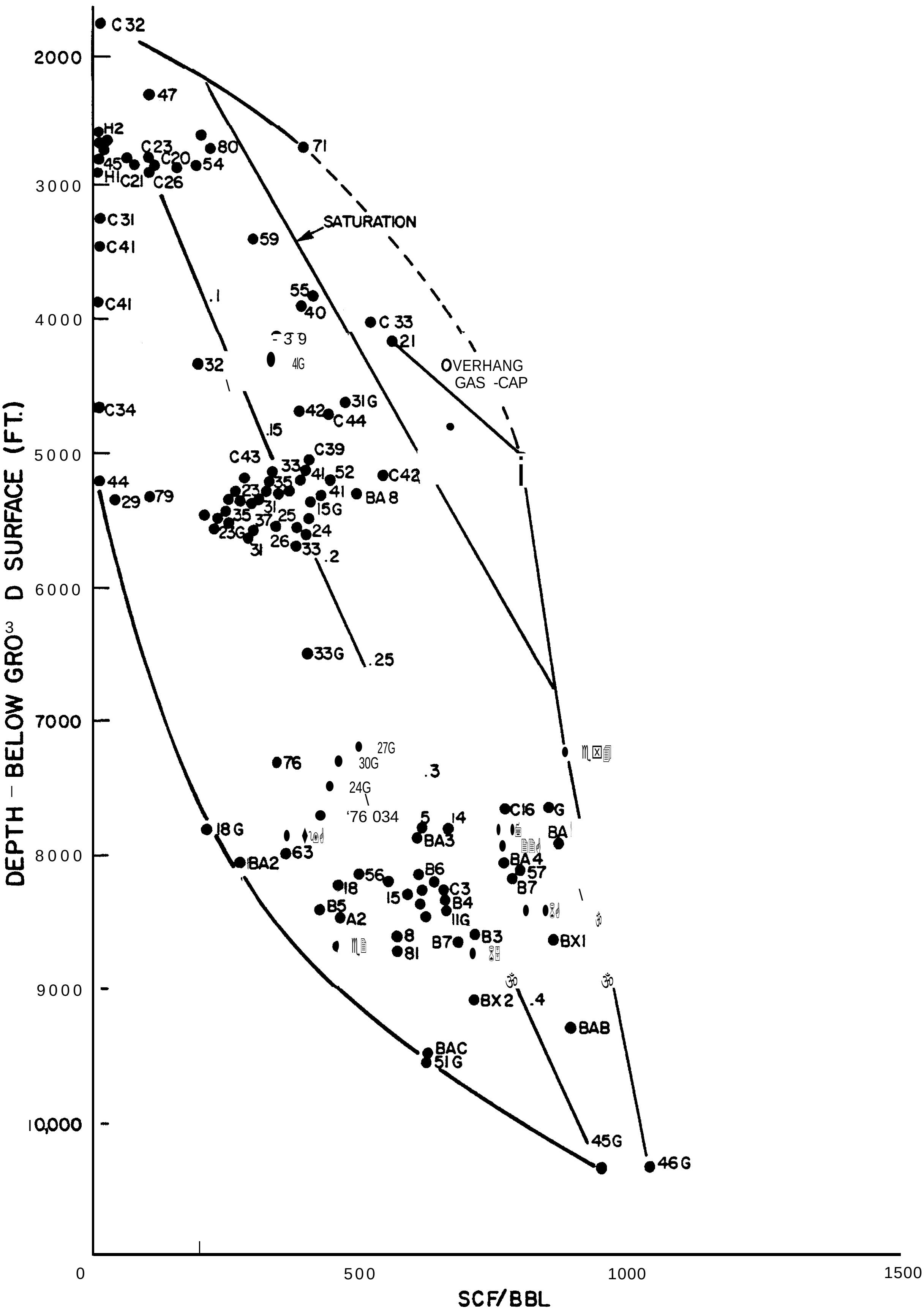
2. BHP - Bottm hole pressure
   BHFP - Bottom hole flowing pressure
   CP - Casing pressure
   TP - Flowing tubing pressure
   SIBHP- Shut-in bottom hole pressure
   SIP - Shut-in pressure
   SITP - Shut-in tubing pressure
   NA - Not available
   P&A - Plugged & abandoned
   TLTM - Too low to measure



BAYOU CHOCTAW SPR SITE
PRESURE -DEPTH PLOT CORRECTED
FOR GAS & OIL COLUMN

ACRES AMERICAN INCORPORATED
T. R. MAGORIAN
OCTOBER 1980

FIG. I



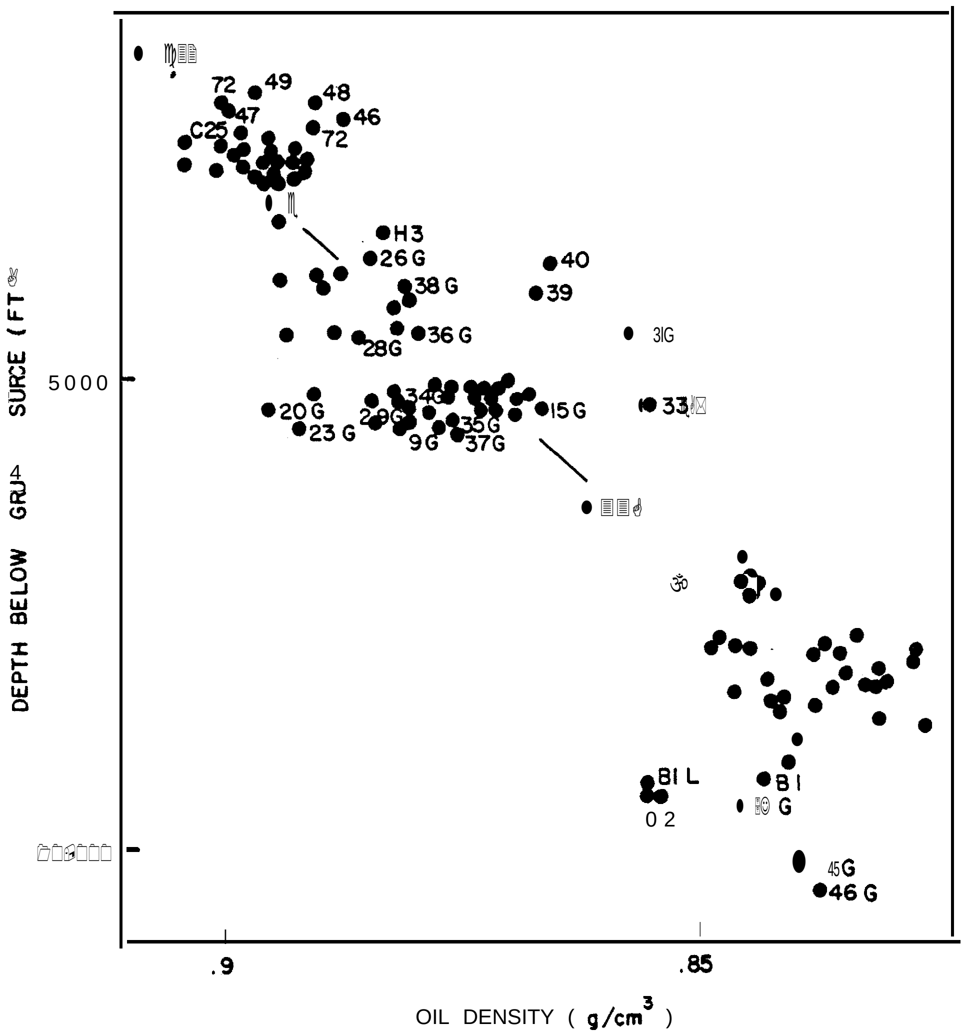
SCF = STANDARD CUBIC FEET OF GAS

BAYOU CHOCTAW SPR SITE
GAS- OIL RATIO

ACRES

ACRES AMERICAN INCORPORATED
T. R. MAGORIAN
OCTOBER 1980

FIG. 2



BAYOU CHOCTAW SPR SITE
DECREASE IN OIL DENSITY WITH OEPTH

ACRES

ACRES AMERICAN INCORPORATED
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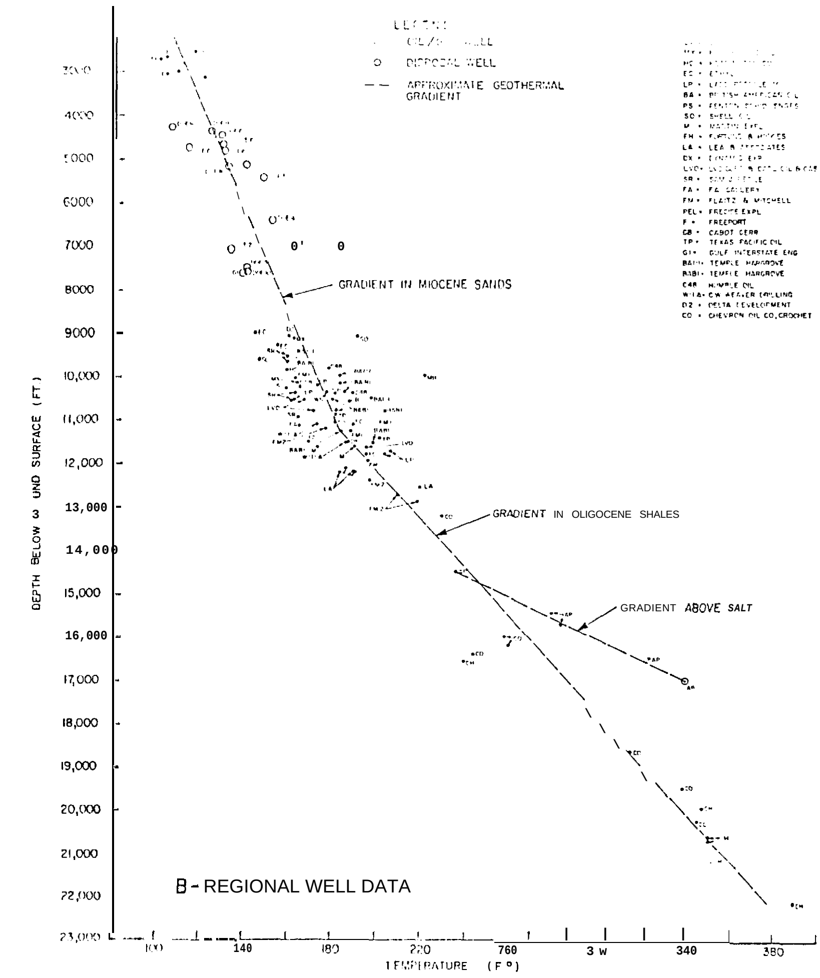
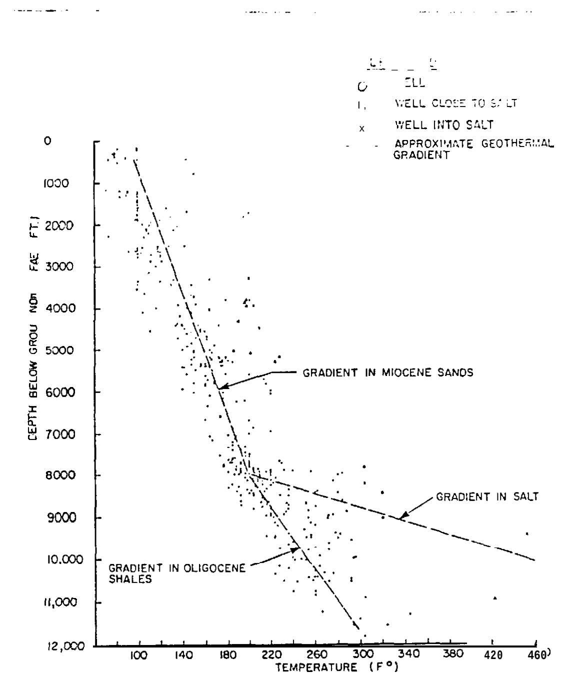
OCTOBER 1980

FIG. 3



B - REGIONAL WELL DATA

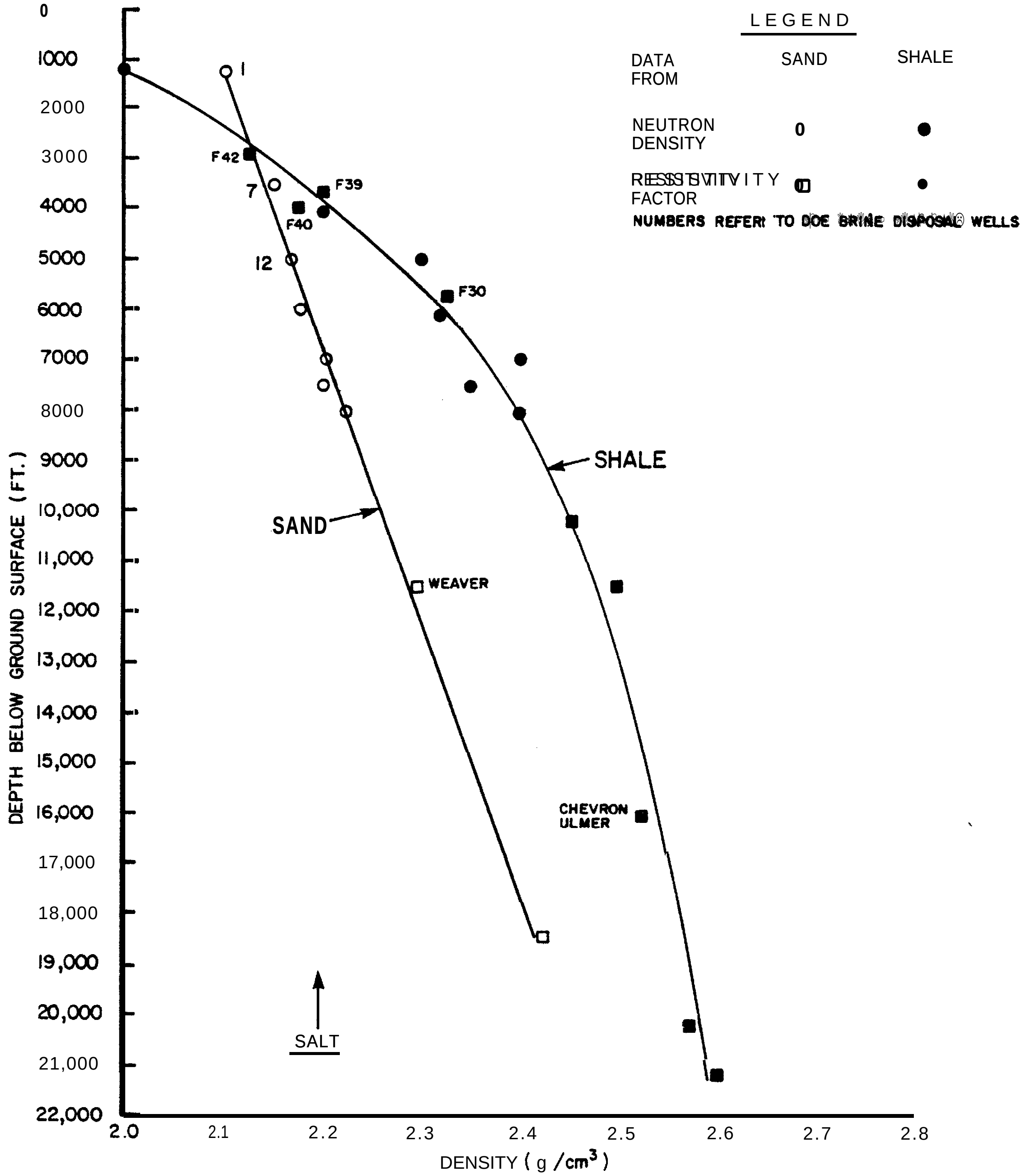


A- BAYOU CHOCTAW SITE DATA

NOTE REFER TO FIG 2 2 FOR WELL LOCATIONS

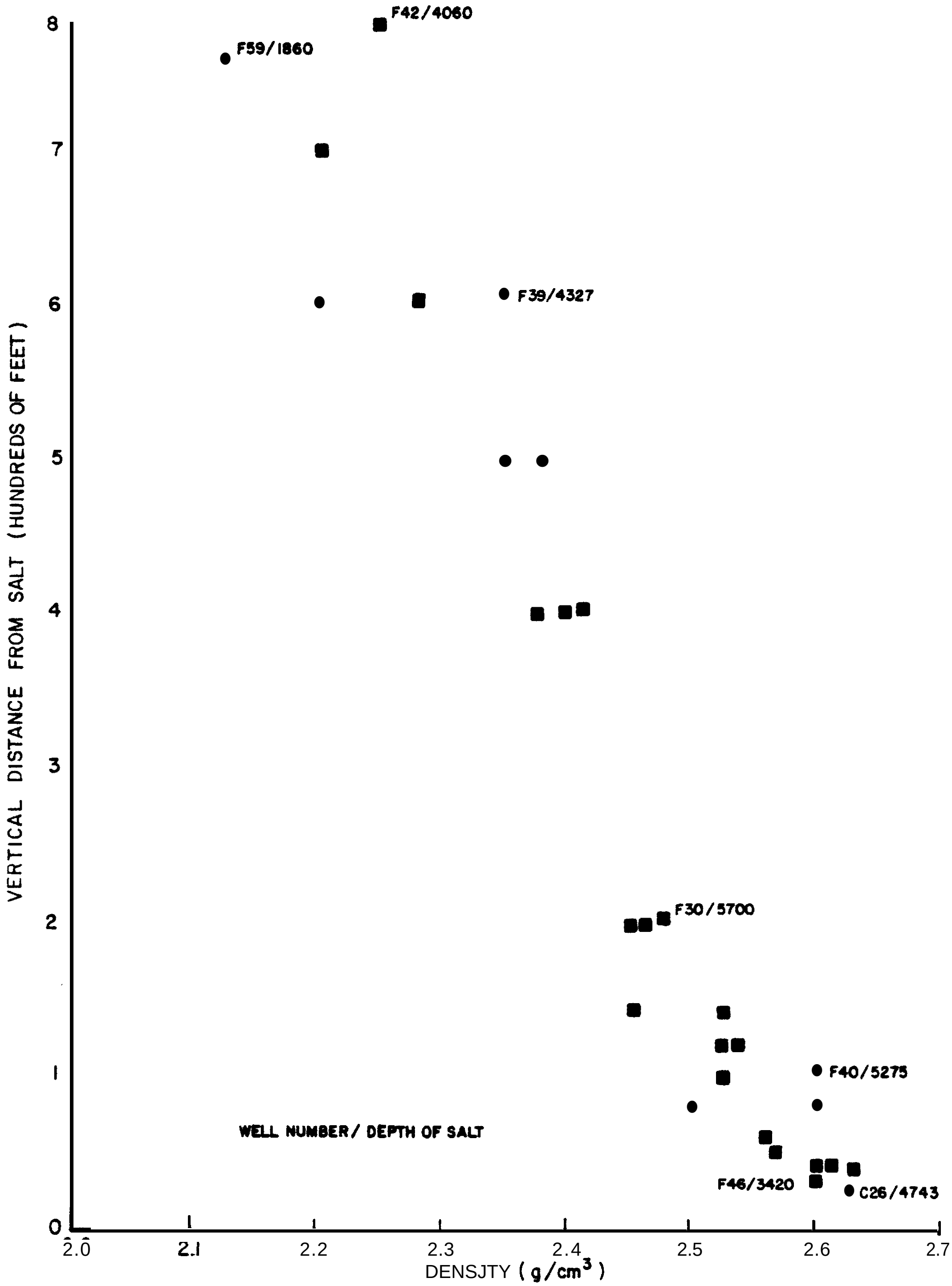
BAYOU CHOCTAW SPR SITE
TEMPERATURE – DEPTH PLOTS

ACRES AMERICAN INCORPORATI
T.R. MAGORIAN
SEPTEMBER 1980 FIG.



BAYOU CHOCTAW SPR SITE
REGIONAL DENSITY

ACRES AMERICAN INCORPORATED
T.R. MAGORIAN
OCTOBER 1980 **FIG. 5**



BAYOU CHOCTAW SPR SITE
INCREASE IN SEDIMENT DENSITY
FROM SALT STRESS

ACRES AMERICAN INCORPORATED
T.R. MAGORIAN
OCTOBER 1980 FIG. 6

ESR Storage Caverns

BAYOU CHOCTAW

Cavern Number	Year Constructed	Volume (mmb)	Oil Stored (mmb)	Type of Oil	DEPTHS - ft: Top of Caprock	Top of Salt	Casing Seat	Top of Cavern	Bottom of Cavern	Cavern Diameter, D	Cavern Height, H	H/D	Nearest Cavern	Distance to Nearest Cavern, P	a/D	Roof Thickness, B	B/D	Distance to Dome Edge, E	E/D	Comments and Recommendations
15	1953	15.7	11.6*	Sour	477	637	2560	2597	3297	350 480[a]	700	2.0	17	57-100	16-.29	2000	5.71	>600	>1.71	Not certified or pressure tested by DOE. Extremely close to cavern 17 which contains ethane @ 2000 psi. PB/KBB recommended limit to 1 cycle unless cavern 17 is obtained or operational agreement is signed. New survey of cavern 17 is recommended. Recommend development and implementation of certification plan (including review of previous tests) for cavern 15 and pursuance with utmost haste agreement concerning (or purchase of) cavern 17. Until this work is completed, recommend no fresh water withdrawal, no intentional depressurization, and close monitoring of well head info.
18	1967	8.5	3.8*	Sour	430	850	1176	110	240	385	2130	5.53	17	380	.99	1260	3.27	780	2.03	This cavern could potentially be effected by uncontrolled leaching of cavern 17.
19	1967	7.5	5.1*	Sour	550	850	2305	2995	4270	264	1275	4.83	16	450	1.7	2145	8.13	500	1.85	Certified as usable for 5 cycles pending information obtained regarding current shape of cavern 16 and future operational plans.
20	1970	5.2	---	---	[illegible]00	680	1085	3980	4306	525	380	.72	NONE CLOSE AT DEFTH			3299	6.28	~~135~~	.26	Close proximity to dome edge will preclude more than 1 fresh water cycle. Recommend additional assessment of dome boundary (possibly including drilling program) and close monitoring of well head pressure and flow information during and after Pilling.

Oil stored as of 2/12/79.

a. Diameter used in SAI cavern stability study.

General Site Comments - Poor quality, thin caprock (mostly gypsum) exists at this site. Major drilling problems were experienced due to loss of circulation near salt/caprock interface and presence of gas in salt-caprock interface. Additional costs and delays should be anticipated at this site for drilling reentry wells and expansion wells.

NOTE : All distances are given in feet.

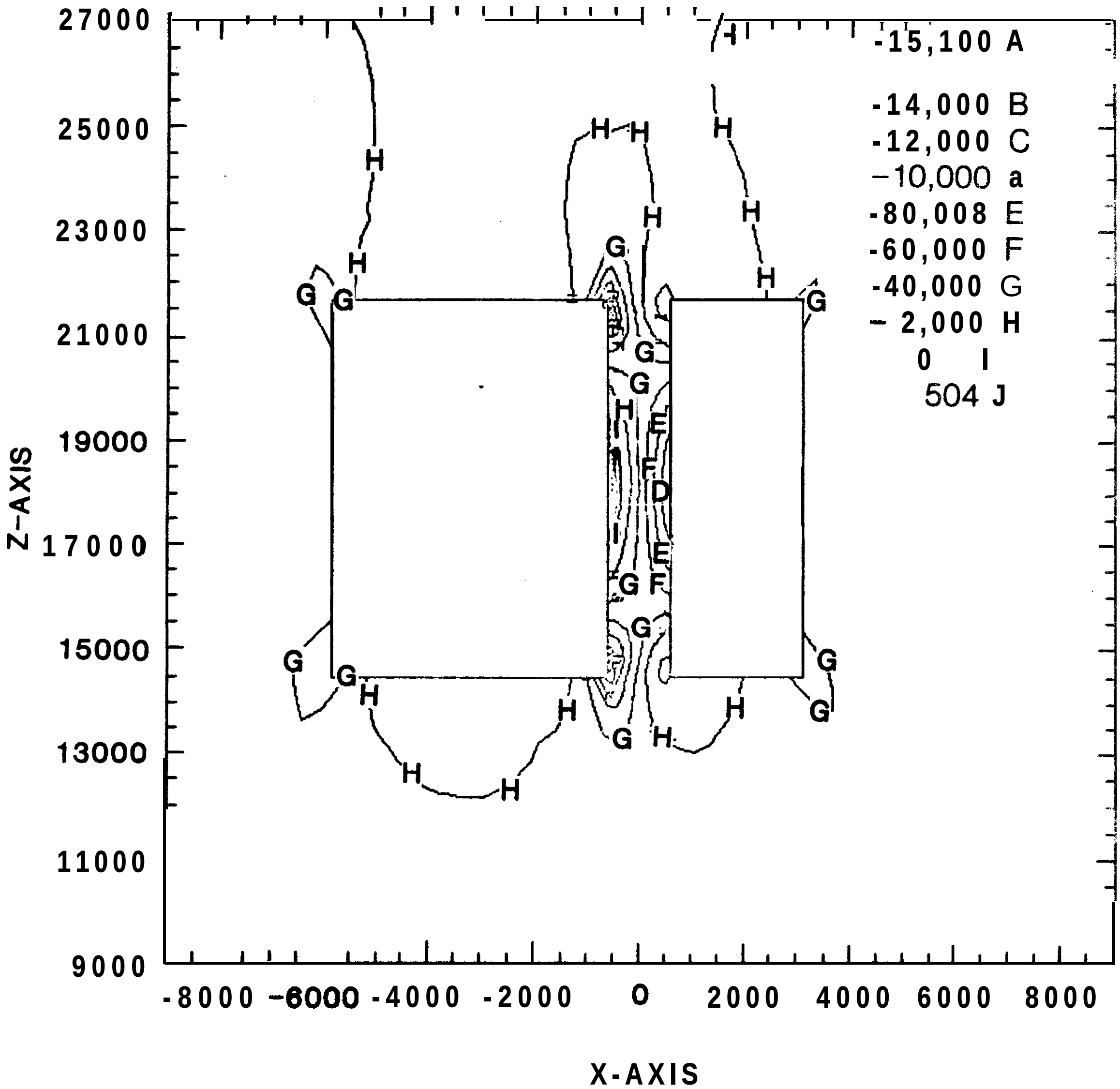


Figure 1. Caverns 15 and 17, Sigma Z (psf)

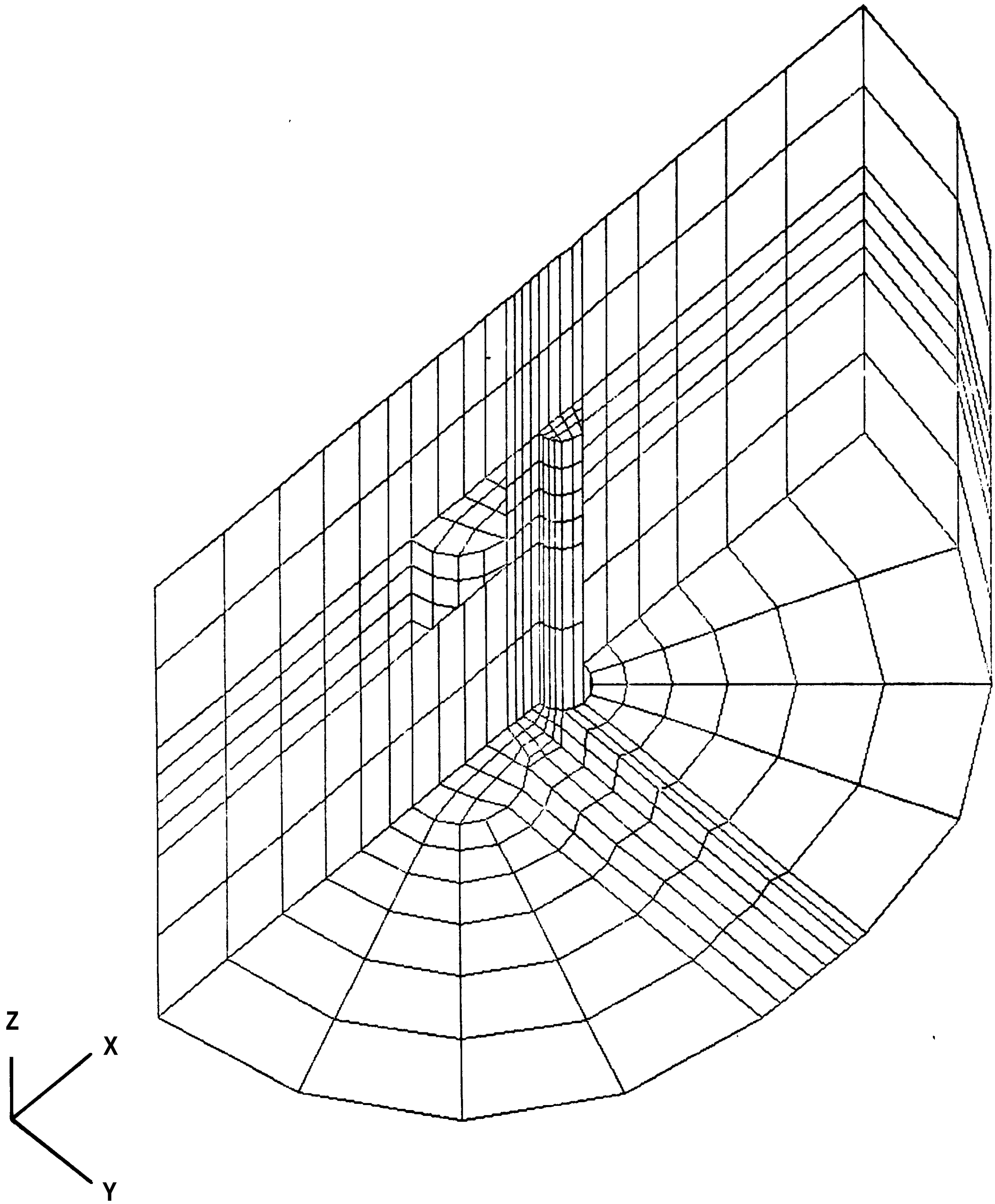


Figure 2. Caverns 15 and 17, Half Section

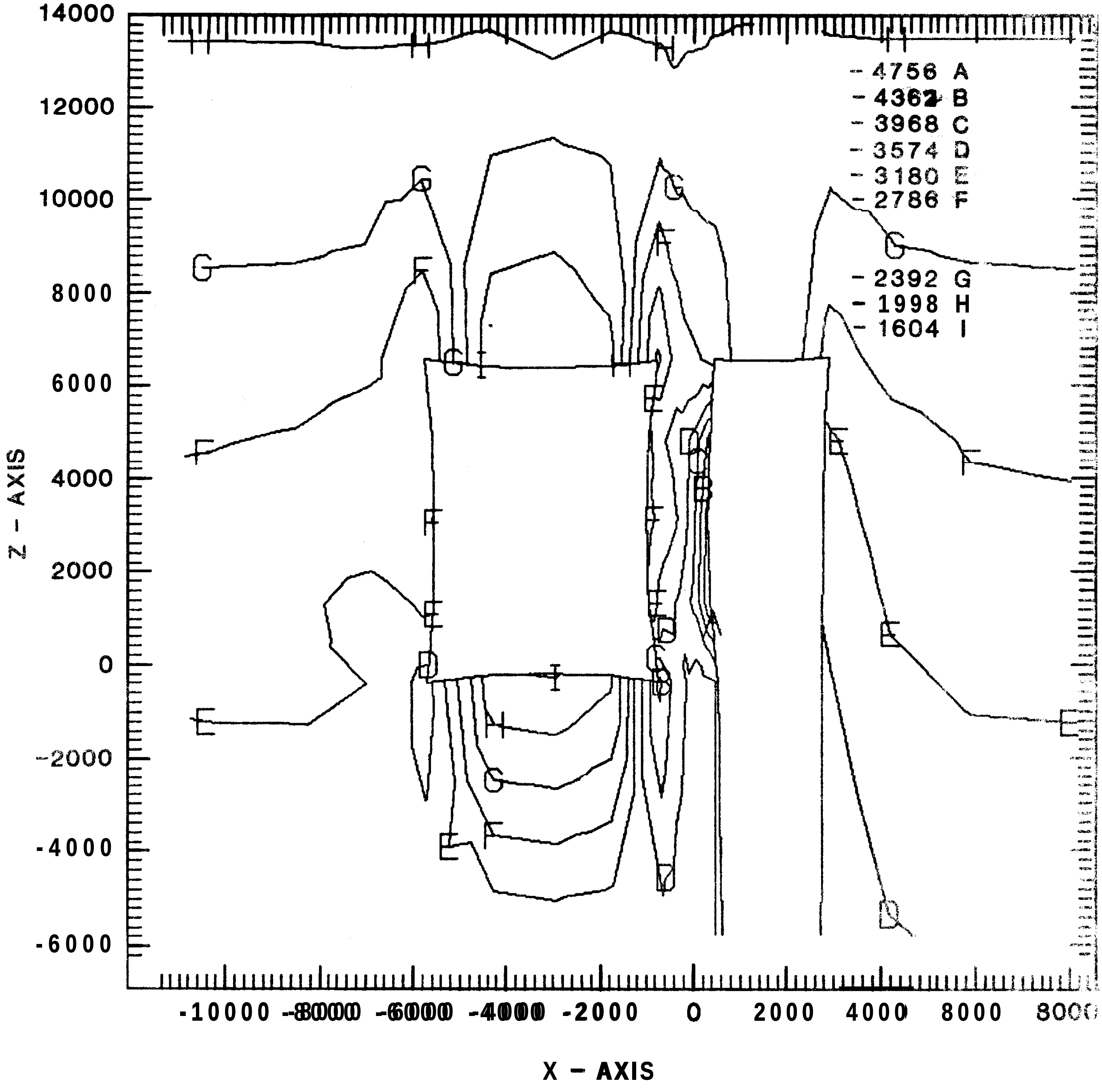


Figure 3. Caverns 15 and 17, Sigma Z (psf)

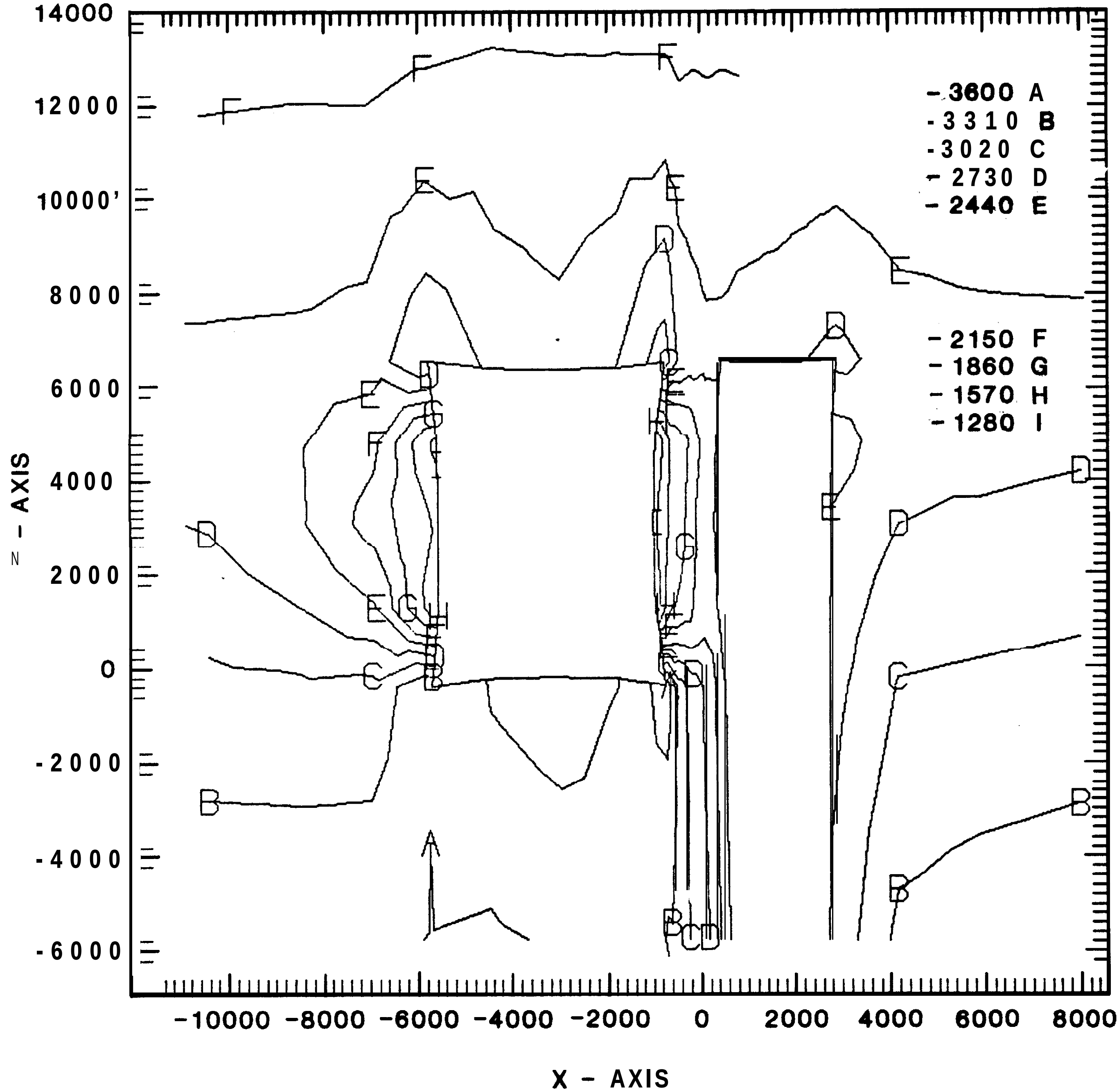


Figure 4. Caverns 15 and 17, Sigma X Stress (psf)

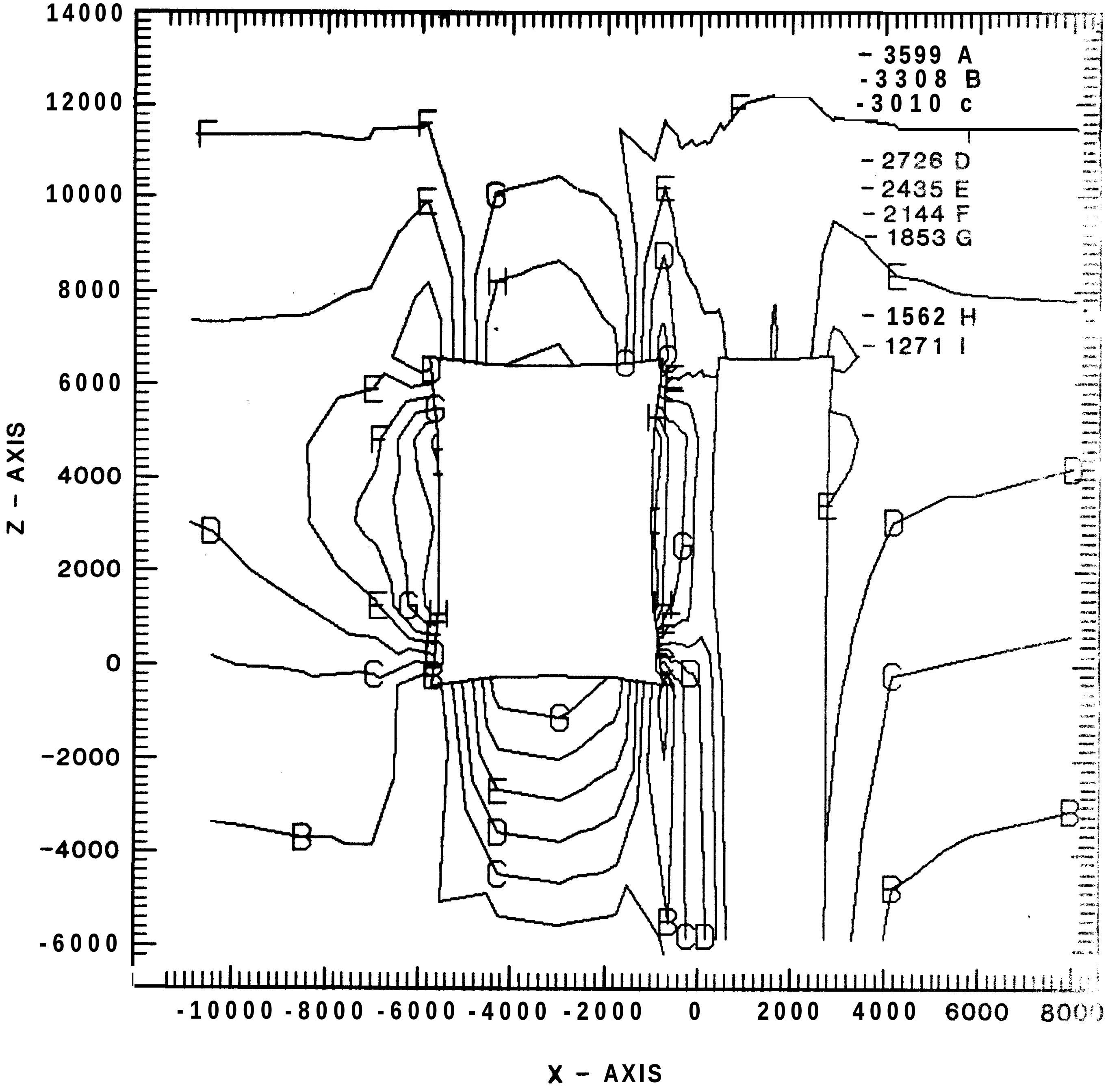


Figure 5. Caverns 15 and 17, Sigma X Maximum (psf)

Introduction and Summary

The US Strategic Petroleum Reserve (SPR) program is currently storing crude oil in Caverns 15, 18, and 19 at the Bayou Choctaw site, and Cavern 20 is being prepared to receive crude oil. Expansion Cavern 102, formerly called Location C, has been surveyed and preparations for drilling and leaching have begun. This report briefly discusses the four caverns mentioned and also a potential subsidence problem at Cavern 4, which is on DOE property but is not suitable for oil storage. Other caverns owned by the DOE have been judged unacceptable for oil storage because they (1) are not pressure-tight, (2) communicate hydraulically with each other, or (3) have thin roofs and are thus structurally questionable.

There are many common issues of concern at each site--depressurization effects, long-term creep closure, etc. The techniques used to address concerns at one site apply at all sites.

A review of cavern stability issues for each SPR site was provided in Reference 1 in 1979. From this blueprint for action, Sandia National Laboratories began a program of geotechnical investigations to support the continued development of the SPR. Initial evaluations of cavern integrity have been based upon the use of generic or "typical" salt properties. These evaluations have attempted to bound concerns associated with creep-closure rates, depressurization of the caverns to zero surface pressure on the oil column, and pillar or web thickness. Concurrently with these evaluations, a materials testing program was begun to characterize the salt from each site. These data will be used in current and future studies to more accurately represent the geomechanical response of existing caverns in the Bayou Choctaw dome and to simulate the additional cavern planned for the dome. Additional data on the failure or fracture of the salt will also provide cavern-specific geological input to leaching-simulation activities. Initial evaluations of cavern integrity were based upon cavern spacing data and dome boundary locations of questionable accuracy. Site characterization activities (Section II) have now brought together more consistent geological and geometrical data on sediments, cap rock, salt stock, and cavern locations that will be valuable in assessing stability concerns.

Site characterizations, and careful consideration of the numerical analyses made to date on dayou Choctaw caverns and caverns in other domes, have resulted not only in several useful observations about the existing caverns but have also helped define additional evaluations that are needed.

In their present configurations, Bayou Choctaw Caverns 18 and 19 currently used for storage of crude oil are geomechanically stable and can be safely operated as storage caverns. Cavern 15 should be operated to the current agreement with Allied Chemical Corporation and should be cycled with saturated brine during withdrawal. Since Cavern 20 is ~130 ft from the edge of the salt dome, we cannot recommend its use until the distance from the cavern to the edge of the dome and the quality of the salt are known.

Existing Caverns at Bayou Choctaw

Table 1 summarizes the geomechanical data for SPR Caverns 15, 18, 19, and 20 in the Bayou Choctaw salt dome. In addition, brief paragraph descriptions, a map, and sonar surveys of the caverns are found in Chapter 6 of Geological Site Characterization of the Bayou Choctaw Salt Dome; by Acres American, Inc. Since the Acres site characterization is bound in this volume as Section III, the information in Chapter 6, "Salt Stock Geology," will not be repeated in this section, which deals primarily with geomechanical issues.

Because the cavern geometry (as related to the vertical and horizontal distances to the dome boundaries and to adjacent caverns) largely governs its suitability for storage from a geomechanics viewpoint, these properties and ensuing ratios to the cavern diameter, D, have been recorded in Table 1. The parameters for the Bayou Choctaw caverns (Table 1) are seen as the bounds on several of the parameters in the overall program.

The distance between adjacent caverns, P, is the current wall thickness (not the center-to-center spacing between caverns) and is used as a measure of the likelihood for cavern coalescence. The P/D ratio indicates the pillar width relative to the cavity size and inversely relates to the intensity of the loading that might be felt in the pillar; i.e., a 100-ft pillar between 500-ft-dia caverns (P/D = 0.2) would be more intensively loaded than if the surrounding caverns at the same depth had only a diameter of 100 ft (P/D = 1).

lhe roof or back thickness, B (amount of salt between cavern roof and the cap rock), is important to cavern stability since the salt must be thick enough to ensure proper grouting of the casing. The B/D ratio indicates the thickness-to-span ratio for the cavern roof. As the B/D ratio decreases to well below 1.0, concern intensifies regarding how adequate the roof materia is for transmitting loads from the cap rock to the cavern walls without developing tensile stresses.

Another parameter, E, that can limit the suitability of an existing cavern for the storage of crude oil is how near the caverns are to the edge of the dome. The salt near the edge of a dome is more likely to be locally fractured and to contain impurities than the salt in the interior of the dome. Any linkage between geologic formations bordering a dome and caverns within the dome must be avoided since the product stored in a cavern could conceivably be lost. Proximity of caverns to the edge of the dome may therefore limit the number of withdrawal cycles of a cavern.

Bayou Choctaw Cavern 15

Because DOE Cavern 15 is estimated to be 100 to 200 ft from Allied Chemical Company's Cavern 17, both are discussed in this section. Cavern 15, a stable configuration of 16.6 MMB, currently contains 8 MMB of crude oil. Cavern 17 is likewise a stable configuration of 12.2 MMB and is used by Allied Chemical Company to store ethane. The ethane pressure is described by the following equation:

$$P_{17} \text{ (psi)} = (0.16) \text{ (depth in ft)} + 1250$$

In 1979 we ran a two-dimensional, vertical, plane-strain, elastic-plastic analysis of the web between the two caverns, using a minimum estimated web thickness of 100 ft. The analysis showed a small region of tensile stress in the web area between the two caverns inside contour line I (Figure 1). This condition existed when Cavern 15 was held at oil-head pressure and Cavern 17 at ethane pressure, in accordance with the above equation.

Our analysts considered this a very conservative solution. Therefore, in 1980 a three-dimensional, elastic-plastic analysis was made by using the same web thickness and pressure conditions of the two-dimensional analysis. For both the two- and three-dimensional analyses a lithostatic loading of 1 psi/ft was simulated on a symmetric half section of the caverns (Figure 2). Cavern 15 is on the left in Figure 2. Figure 3 shows a vertical (Z) stress on a plane through the centerlines of both caverns. Unlike the two-dimensional analysis, no tensile stress appears in the web from this model. We believe this is the most representative answer. Figure 4 shows the horizontal (X) stress in a plane perpendicular to the cavern axes; no tensile stress appears in the web. Figure 5, perhaps the most interesting, shows the maximum stress in the plane of Figure 4. Again, there is no area of tensile stress in the web, and the value shown closest to tension is 985 psi in compression. Based upon the more valid three-dimensional analysis, we believe that the 100-ft web under the pressure conditions given provides structural adequacy for SPR use.

Bayou Choctaw Cavern 18

According to a 1978 sonar survey, Cavern 18 is a tall, candle-shaped cavern extending from 2100 to -4200 ft, with diameters varying from-60 ft at the top to 300 ft at the bottom. This cavern should be very stable since the distance to cap rock, edge of dome, or other caverns is more than adequate. The shape is quite regular, with no salt ledges or other anomalies indicated on the sonar survey.

Bayou Choctaw Cavern 19

Cavern 19 is an ideally shaped cavern extending from 3000 to 4200 ft in depth with an average diameter of -200 ft. It is well-separated from other caverns and the edge of the dome. The shape is very regular, with no ledges or other anomalies. Nothing in the history of this cavern or in its geometry causes us to doubt its structural integrity.

Bayou Choctaw Cavern 20

A two-dimensional, plane-strain, elastic-plastic analysis was made of Cavern 20 to determine minimum edge-of-dome thickness. The parameters used in this analysis were oil-pressure head on the cavern, a 100-ft-thick cavern web at the edge of the dome, and lithostatic pressure on the exterior of the salt dome. The horizontal, plane-strain slice was assumed at a maximum cavern depth of 4305 ft and a maximum cavern diameter of 500 ft. Figure 6 shows the finite-element mesh picture of the geometry analyzed. Figure 7 shows a plot of the maximum tensile stresses produced in the area most likely to exhibit such stresses. No tensile stress developed, indicating that a competent salt web 100 ft thick is adequate to withstand cavern depressurization to oil-head pressure. However, competent salt would mean an inclusion-free zone (see Section II, paragraph 6.3.4), and that is very difficult to guarantee without an experimental program.

Bayou Choctaw Expansion Cavern 102

Four potential cavern locations have been proposed in an earlier study[2] and have been described in detail by Acres American, Inc., in Chapter 6 of their <u>Geological Site Characterization of the Bayou Choctaw Salt Dome</u> (see Section II of this volume). Figures 6-14, 6-31, and 6-32 in the Acres SK-tion show both the locations and radial sections through the proposed caverns to the edge of the salt dome. Location A was judged unacceptable, Locations B and D potentially acceptable if additional geophysical work supports that view, and Location C was judged acceptable.

Our investigation of expansion cavern locations A, B, C, and D raised concerns about Cavern 4. Cavern 4 was abandoned by Allied Chemical Company ~25 years ago as a brine cavern. The cavern now extends -30 ft into the 120-ft-thick massive gypsum-anhydrite cap rock. Many similarities are observed between former Cavern 7 (now Cavern Lake) and Cavern 4. Aerospace Corporation has been asked by the DOE to assess the risks of Cavern 4 for SPK operations at the site. Sandia has been asked to consider ways of stabilizing Cavern 4 in an attempt to preclude a repetition of what happened at Cavern 7. Both Aerospace and Sandia are continuing their activities at this time, and nothing further can be said of the subject in this paper.

References

1. <u>Systems Integration and Engineering Support Study for the Strategic Petroleum Reserve (SPR) Program - Final Report</u>, SAND79-0637 (Albuquerque, NM: Sandia National Laboratories, June 1979).

2. Jacobs/D'Appolonia architectural engineering firms, New Orleans office, "Surge Cavern Feasibility Study," R010, January 1980.

ESR Storage Caverns

BAYOU CHOCTAW

Cavern Number	Year Constructed	Volume (mmb)	Oil Stored (mmb)	Type of Oil	Top of Caprock (DEPTHS - ft)	Top of Salt (DEPTHS - ft)	Casing Seat (DEPTHS - ft)	Top of Cavern (DEPTHS - ft)	Bottom of Cavern (DEPTHS - ft)	Cavern Diameter, D	Cavern Height, H	H/D	Nearest Cavern	Distance to Nearest Cavern, P	a/D	Roof Thickness, B	B/D	Distance to Dome Edge, E	E/D	Comments and Recommendations
15	1953	15.7	11.6*	Sour	477	637	2560	2597	3297	350 480[a]	700	2.0	17	57-100	16-.29	2000	5.71	>600	>1.71	Not certified or pressure tested by DOE. Extremely close to cavern 17 which contains ethane @ 2000 psi. PB/KBB recommended limit to 1 cycle unless cavern 17 is obtained or operational agreement is signed. New survey of cavern 17 is recommended. Recommend development and implementation of certification plan (including review of previous tests) for cavern 15 and pursuance with utmost haste agreement concerning (or purchase of) cavern 17. Until this work is completed, recommend no fresh water withdrawal, no intentional depressurization, and close monitoring of well head info.
18	1967	8.5	3.8*	Sour	30	850	1176	110	240	385	2130	5.53	17	380	.99	1260	3.27	780	2.03	This cavern could potentially be effected by uncontrolled leaching of cavern 17.
19	1967	7.5	5.1*	Sour	50	850	2305	2995	4270	264	1275	4.83	16	450	1.7	2145	8.13	500	1.85	Certified as usable for 5 cycles pending information obtained regarding current shape of cavern 16 and future operational plans.
20	1970	5.2	---	---	00	680	1085	3980	4306	525	380	.72	NONE CLOSE AT DEFTH			3299	6.28	135	.26	Close proximity to dome edge will preclude more than 1 fresh water cycle. Recommend additional assessment of dome boundary (possibly including drilling program) and close nonitoring of well head pressure and flow information during and after Pilling.

Oil stored as of 2/12/79.

a. Diameter used in SAI cavern stability study.

General Site Comments - Poor quality, thin caprock (mostly gypsum) exists at this site. Major drilling problems were experienced due to loss of circulation near salt/caprock interface and presence of gas in salt-caprock interface. Additional costs and delays should be anticipated at this site for drilling reentry wells and expansion wells.

NOTE : All distances are given in feet.

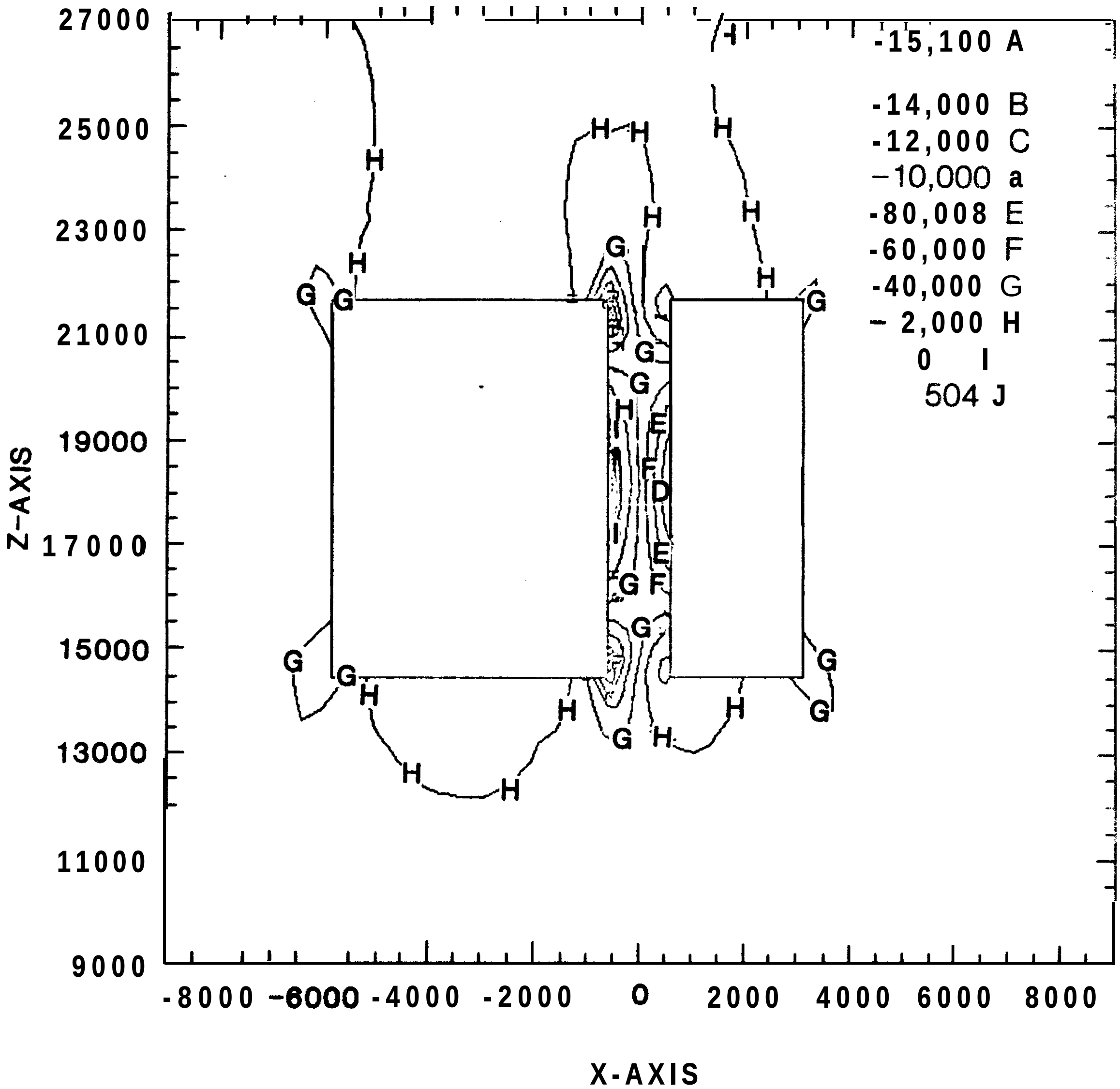


Figure 1. Caverns 15 and 17, Sigma Z (psf)

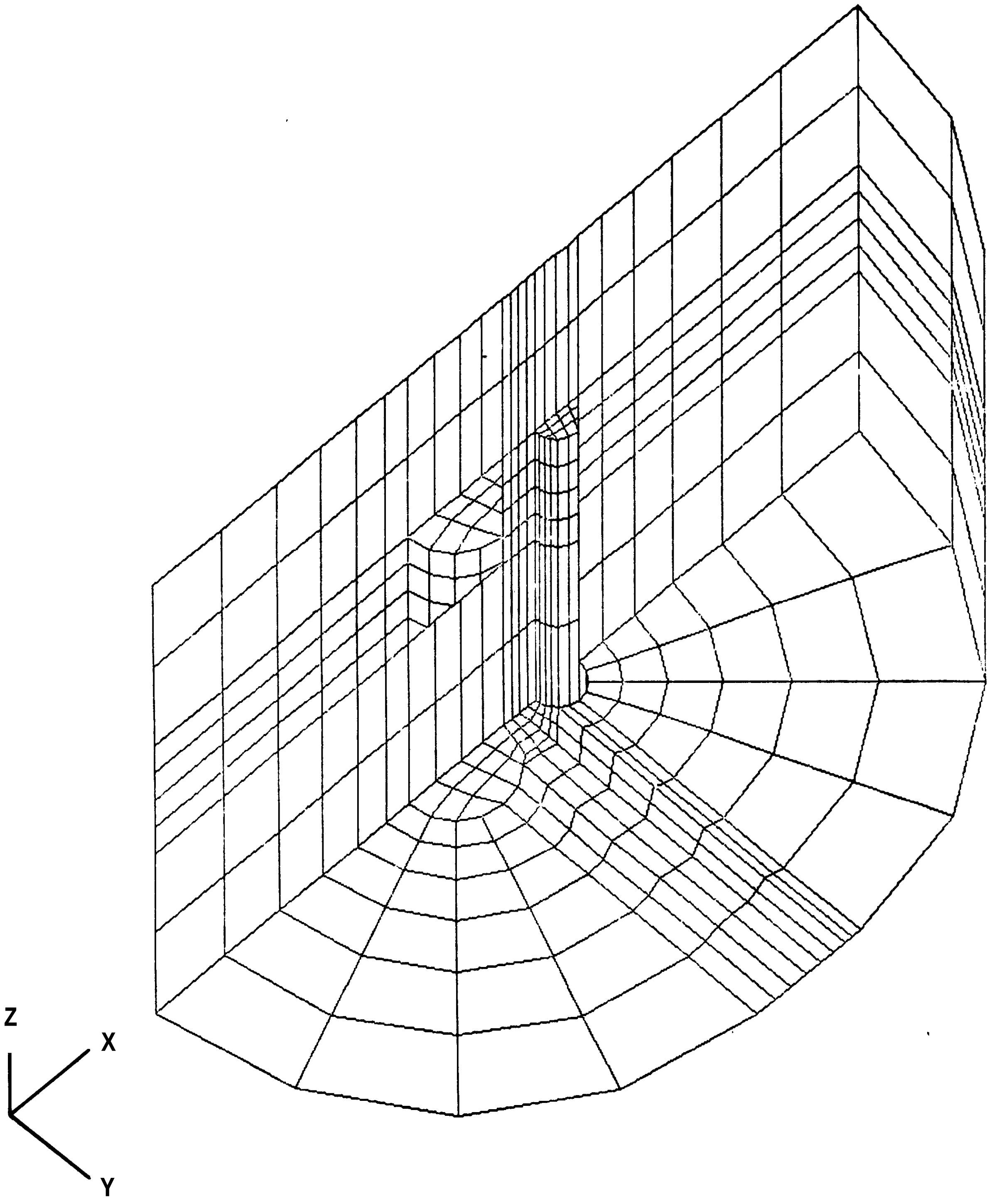


Figure 2. Caverns 15 and 17, Half Section

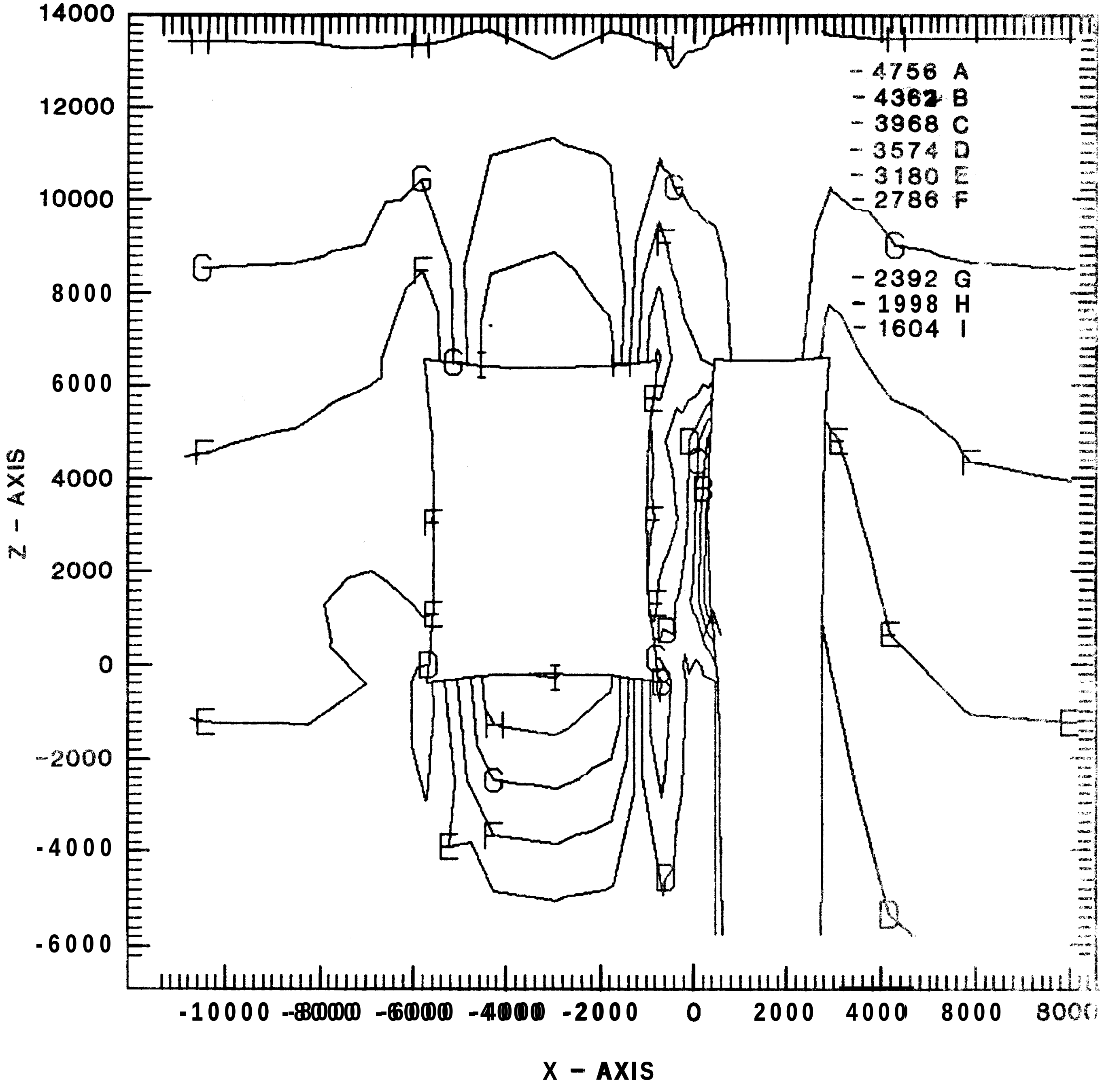


Figure 3. Caverns 15 and 17, Sigma Z (psf)

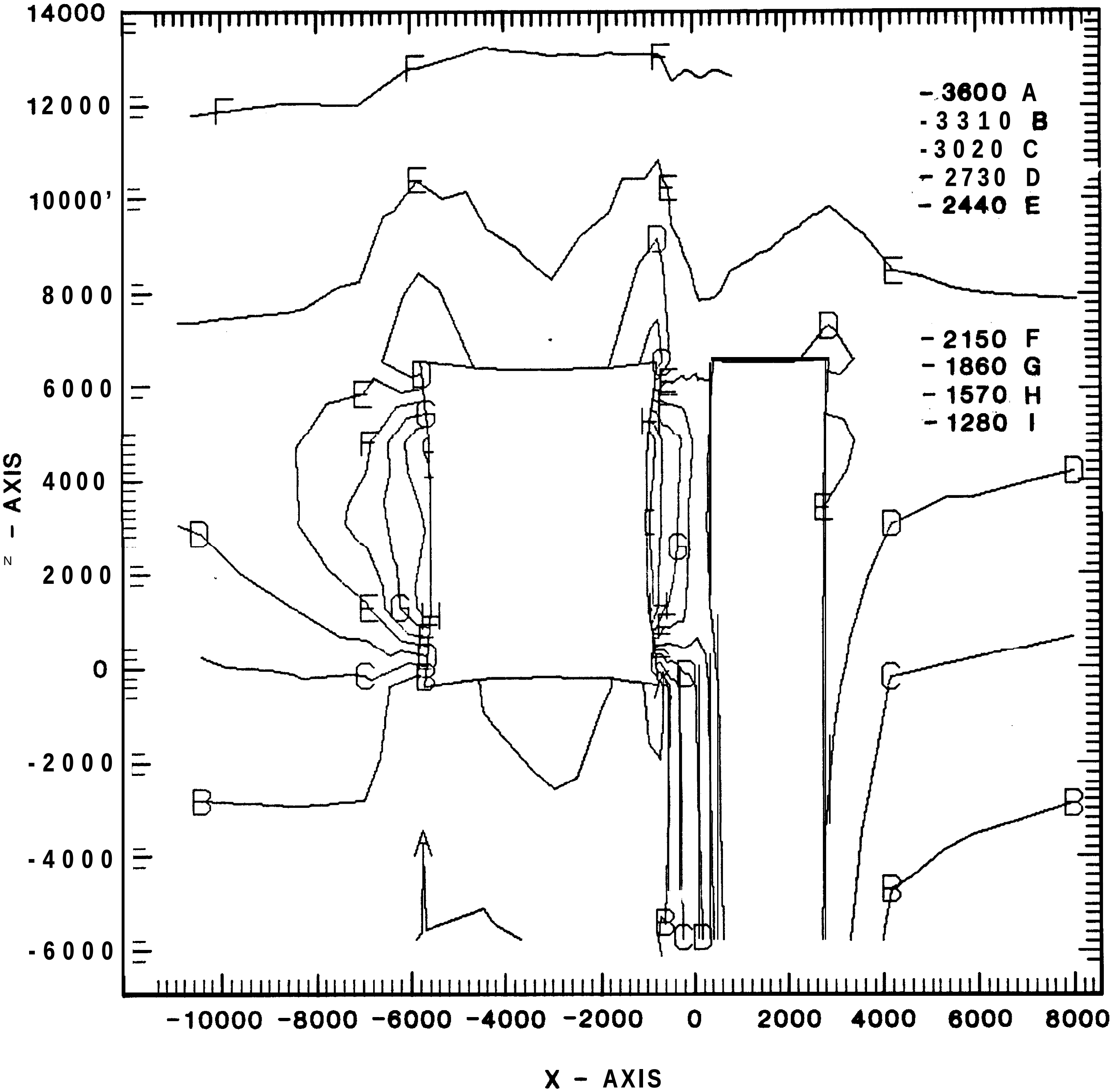


Figure 4. Caverns 15 and 17, Sigma X Stress (psf)

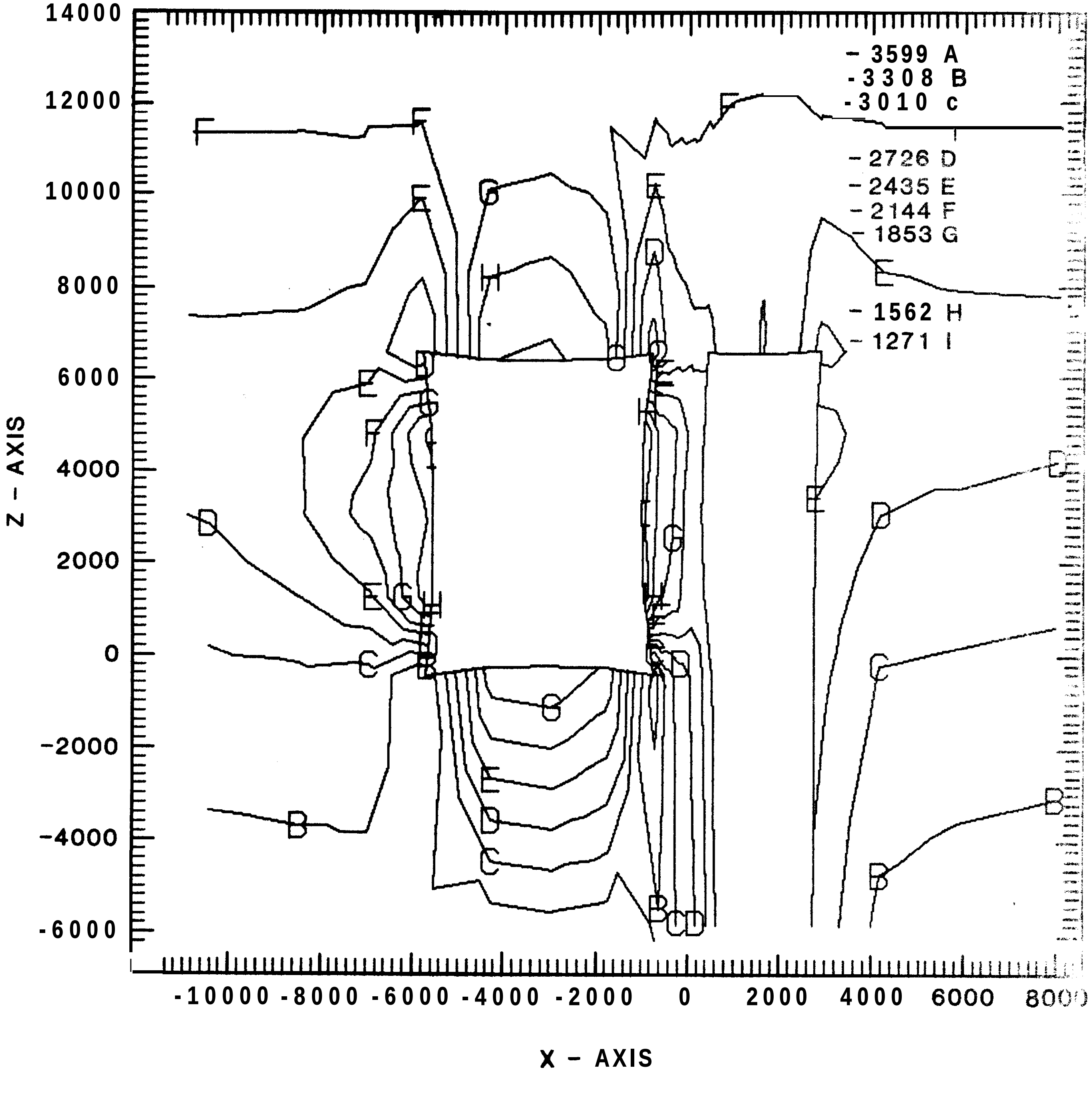


Figure 5. Caverns 15 and 17, Sigma X Maximum (psf)

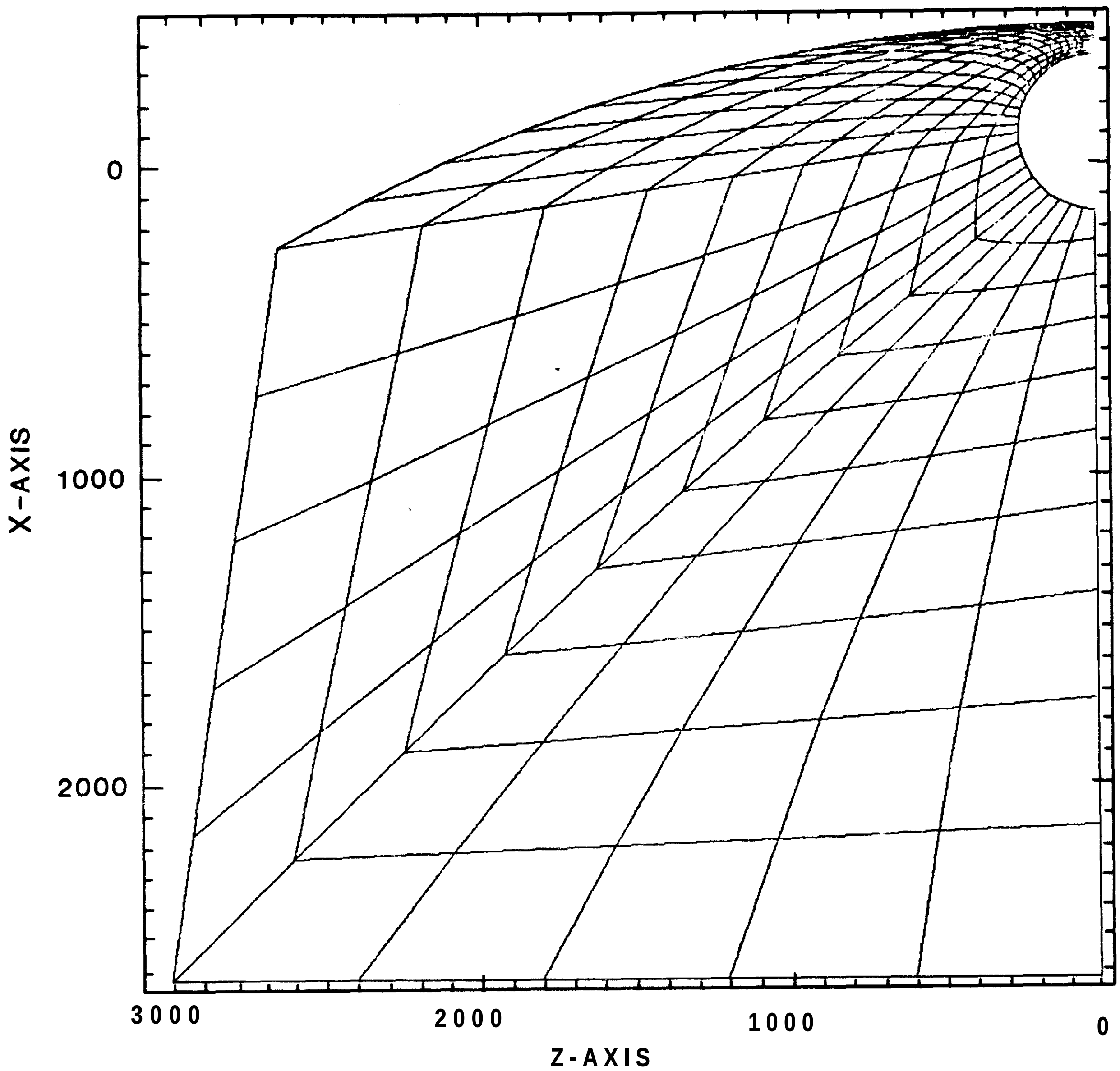


Figure 6. Cavern 20 to Edge of Dome

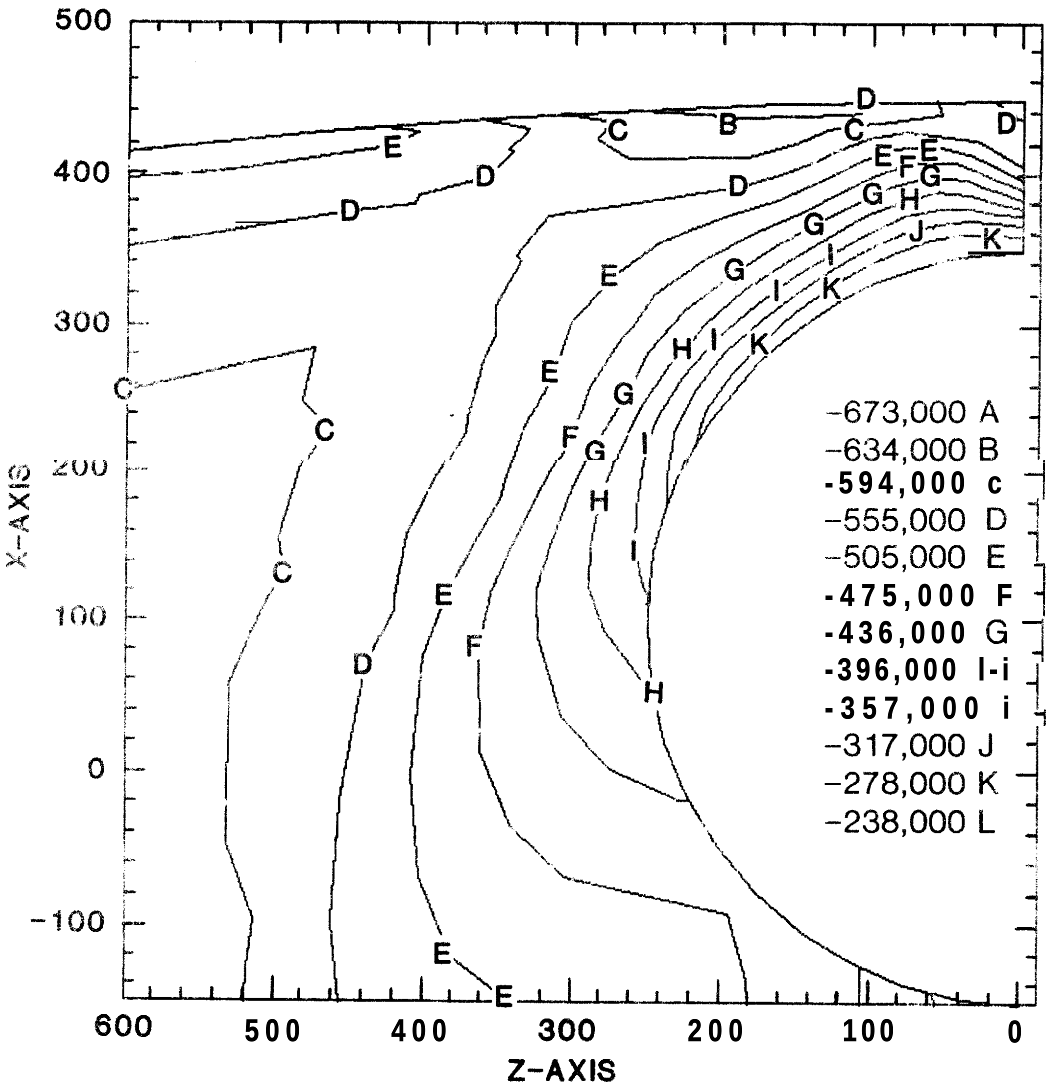


Figure 7. Cavern 20 to Edge of Dome, Sigma Z (psf)

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SECTION III

SALT PROPERTIES FOR BAYOU CHOCTAW SPR

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GEOLOGICAL SITE CHARACTERIZATION

BAYOU CHOCTAW

SPR PROGRAM

PHASE 1 REPORT

SEPTEMBER 1980

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ACKNOWLEDGEMENTS

This study has had the support and direction of Robert Hogan, James Ney and Morgan Kramm along with entire SPR staff at Sandia National Laboratories, including R.J. Hart and Clyde Walker in New Orleans as well as Robert Mazurkiewicz, Donald Whittington and James Carne of DOE SPR PMO, New Orleans, and Richard Smith of DOE, Washington.

TABLE OF CONTENTS

TABLE OF CONTENTS - 2

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

APPENDIX A

Table A-1	Depths to Pliocene through Number 5 Sand
Table A-2	Depths to Number 6 Sand through Nodosaria Blanpiedi Zone
Table A-3	Depths to Caprock and Salt

APPENDIX B

B-1	Section M-M'
B-2	Section N-N'
B-3	Section O-O'
B-4	Section P-P'
B-5	Section Q-Q'
B-6	Section R-R'
B-7	Section S-S'
B-8	Section T-T'

1 - SUMMARY AND CONCLUSIONS

1.1 - Summary

1.1.1 - Introduction

The Bayou Choctaw salt dome, located in south-central Louisiana, was discovered in 1926 and since then over 300 oil and gas wells have been drilled on and around the dome and shallow holes drilled into the caprock. Since 1937, Allied Chemical Corporation (formerly Solvay Process Company) has drilled over 20 brine wells on the dome. In 1976, the Department of Energy (DOE) purchased 11 of these leached caverns and is currently storing a total of approximately 22 million barrels of crude oil in three of the caverns numbered 15, 18 and 19 forming part of the Strategic Petroleum Reserve Program.

The Phase I Geological Site Characterization for the Bayou Choctaw Strategic Petroleum Reserve (SPR) Site was performed by Acres American Incorporated, Buffalo, New York in association with Dr. T. R. Magorian, Consulting Geologist and Geophysicist, under Contract Document No. 46-6273 with Sandia National Laboratories.

The objectives of the study were to:

a. Acquire, compile, evaluate and interpret existing data pertinent to the geological characterization of Bayou Choctaw;

b. Characterize the surface and near surface geology and hydrology;

c. Define the geological, hydrological and geophysical characteristics of the caprock;

d. Define the geometry and geology of the dome;

e. Assess effects of natural events;

f. Provide geotechnical advice on Expansion Cavern locations A, B, C and D.

All interpretations and analyses performed for this study were based on existing data collected from public and private sources. The report is summarized below and the conclusions are presented in Section 1.2.

1.1.2 - Geologic Setting

The geologic history of the Gulf Coast began with the opening of the Atlantic during the Triassic period (See Table 3.1) and the formation of the Sigsbee Deep, a large depositional basin in the center of the Gulf. From the Triassic to the present, the Gulf Coast geosyncline has been filling with thick sequences of sand, silts, clays and evaporites.

The thickness of these sediments at the Bayou Choctaw site are on the order of 30,000 feet. Under the accumulated weight of the sediments, lighter rocks such as salt and geopressured shale, rose in domes and diapirs. Faulting in the Gulf Coast geosyncline consists of regional growth faults related to subsidence in the basin and small, local faults associated with the emplacement of salt domes.

1.1.3 - Surface and Near-Surface Geology

The surface and near surface sediments overlying the Bayou Choctaw dome are of Pleistocene through Holocene age. The oldest sediments consist of proglacial sands and gravels with some clay layers. These sediments are overlain by an alternating sequence of sands, silts and clays. The upper 60 feet of sediments consist of the Atchafalaya Clay, a post-glacial backswamp sediment.

The principal aquifer at the site is the Plaquemine Aquifer of Pleistocene age. This unit lies approximately 60 feet below the surface and extends to a depth of between 500 and 600 feet. Groundwater flow in the Plaquemine is away from the Mississippi during the high stage and towards the river during the low stage. The coefficient of permeability for this aquifer is estimated to be in the range of 1,900 to 2,500 gallons per day per square foot. The freshwater/saline water interface occurs at a depth of 400 to 500 feet below the surface. Salt dissolution rates calculated using a simple diffusion/dispersion model are of the order 1.6 x 10^{-5} in/year.

1.1.4 - Caprock

Two distinct zones are found in the caprock at Bayou Choctaw: an upper zone, termed the clay and gypsum zone; and the lower zone, called the massive gypsum-anhydrite zone. The clay and gypsum zone is composed of layers of gypsum intercalated with clay. This zone is up to 150 feet thick and lies within 400 to 450 feet of the surface. The massive gypsum-anhydrite zone is the lower unit and consists of gypsum-anhydrite with some clay and sand. A discontinuous massive layer of gypsum-anhydrite, 20 to 60 feet thick, marks the top of this zone which lies within 500 to 600 feet of the surface. The zone is generally between 100 to 200 feet thick and extends to a depth of approximately 1,500 feet. Faults and fractures in the caprock, formed by salt solutioning and collapse at the salt/caprock contact, result in a highly permeable and discontinuous unit with little structural strength.

1.1.5 - Salt Dome

The top of the Bayou Choctaw dome lies between 600 and 700 feet below the surface. The east flank dips gently downward to 1,500 feet where the dip increases to approximately 80" between 2,000 and 6,000 feet. The west flank of the dome is overhung between 1,000 and 5,000 feet. Below 6,000 to 8,000 feet around the dome, the slope of the salt surface begins to flatten toward 60°. Calculations show an average dome growth rate between 2.8 x 10^{-4} to 3.5 x 10^{-4} in/year since the end of the Pliocene.

Zones of salt inclusions (areas of detached salt blocks), frequently 300 feet thick, have been mapped around the north and south side of the dome. The sediments around the dome have been faulted by radial and tangential faults which developed as the dome moved upwards. Several of the faults may be "active" in that they appear to displace recent sediments over the dome. The most problematic fault, as it relates to the SPR facilities, is an active east-west trending tangential fault along the northern edge of the dome.

1.1.6 - Hazards

The effects of hazards such as hurricanes, flooding, earthquakes, natural subsidence and cavern collapse have been evaluated. Two principal hazards exist at Bayou Choctaw that could severely effect the SPR facilities; flooding of the site and the potential collapse of Cavern 4.

Flood waters, reaching a maximum elevation of +14 feet, can be expected at the site every two years. The site elevation ranges from +5 to +10 feet and so the potential for flooding is quite high and is considered to be a serious problem which could result in the temporary loss of facilities at the site.

The nearest recorded earthquake to Bayou Choctaw occurred at Napoleonville, Louisiana on December 19, 1930, forty miles to the southeast. The intensity was VII (Modified Mercalli) at the epicenter but was estimated to be IV in the site area. Sediment loading on the Baton Rouge fault is interpreted to be the cause of the earthquake. An earthquake of intensity VI I occurring at the site is unlikely to cause damage to surface structures or underground openings.

A subsidence survey at Bayou Choctaw indicated typical subsidence rates of 0.01 to 0.02 feet per year for survey points not located over a cavern. Higher rates, from 0.03 to 0.05 feet per year, were recorded over the caverns. A possible subsidence of three feet has occurred in the vicinity of Cavern 4. Whether this subsidence is due to the compaction of the unconsolidated clay beneath these newly constructed brine pond or to instability of Cavern 4 is not known. Facilities constructed at the site may experience some settlement, but it is probable that the settlement would not severely affect well-engineered structures.

Recent surveys indicate that the roof of Cavern 4 extends 30 feet into the massive caprock zone. The situation currently existing at Cavern 4 is similar to that which existed at Cavern 7 prior to its collapse in 1954. It is estimated that if Cavern 4 were to collapse, the maximum cone of surface depression would form an 800 foot diameter circle centered over the point of roof failure. Insufficient geotechnical modelling and data however, prohibits the quantitative determination of the mode or time of failure.

1.2 - Conclusions

The following conclusions are based on a review and interpretation of all available data.

a. Well data on and around the site are generally sufficient for interpreting the local stratigraphy, structure, and dome geometry and geology.

b. The roof of Cavern 4 has been eroded at least 30 feet into the overlying caprock. Similar conditions that led to the collapse of Cavern 7 in 1954 are present at Cavern 4. Indications are that collapse of Cavern 4 will occur; however, insufficient data are available to quantify the mode and/or time of collapse.

c. Eleven major faults have been mapped at Bayou Choctaw (Section 6). Three of these faults (F-1, F-2 and F-3) may be active. Fault F-1 strikes through the northern part of the dome and may ultimately have been the cause of the Cavern 7 collapse. Fault F-2, trending across the southern flank of the dome, appears to strike through the southern caverns. These caverns, however, are pressure tight suggesting that this fault has been healed by salt creep. Fault F-3 strikes north-south across the east flank and dips to the east but does not intersect the salt. No evidence of active faulting has been found on the west flank of the dome. It is likely that the movement on most faults, if any, is slow enough that salt creep can seal the fracture.

d. Cavern 20 has been leached to within an estimated 130 feet of the dome edge. The study of the dome edges show that impure salt and inclusions may extend 300 feet into the salt from the mapped boundaries.

   It is for this reason that previous studies have recommended that a minimum 300-foot buffer zone be maintained between the salt edge and oil storage caverns.

e. Detailed interpretations of the proposed Expansion Cavern locations for ethane storage showed that:

   i Location A would intersect the edge of the dome;

   ii Location B may fall within the zone of collapse if Cavern 4 were to fail;

   iii Location C is acceptable; and

   iv Location D was sited in an area of faulted salt subject to subsidence.

f. Site flooding poses a chronic problem. All major surface facilities are below flood stages and flooding of the site occurs approximately every two years.

g. Subsidence is not a potential local problem at the site.

2 - INTRODUCTION

2.1 - Scope and Purpose

Sandia National Laboratories has been given the responsibility for the Geotechnical Program for the Department of Energy's Strategic Petroleum Reserve (SPR). The overall scope of the program includes all of the geotechnical investigations necessary to support the SPR Program. Site-specific efforts have been directed in five areas:

1. site characterization
2. engineering design assistance and evaluation (including numerical simulation studies);
3. laboratory and bench scale testing of salt and other materials from the SPR sites;
4. instrumentation development and evaluation; and
5. monitoring and interpretation of field events.

This report has been prepared as a comprehensive Phase I geological site characterization program for the Bayou Choctaw SPR Site under Sandia contract document 46-6273 to Acres American Incorporated of Buffalo, New York, in association with Dr. Thomas R. Magorian, Consulting Geologist and Geophysicist. This phase of work consists of compilation, analysis and interpretation of existing data and data being generated as part of current SPR activities. Specific tasks were:

1. Acquisition, compilation, evaluation and interpretation of existing data pertinent to the geological characterization of the Bayou Choctaw SPR Site. All available data from public and private sources were obtained under this task.
2. Characterization of the surface and near surface geology and hydrology with respect to its impact on the SPR facilities.
3. Geological, hydrological and geophysical characterization of the caprock.
4. Characterization and geometrical definition of the salt dome including accurate mapping of the salt dome boundaries, analysis of salt cores, and a review of all drilling activities which penetrated the salt.
5. Assessment of possible effects of natural events (i.e. hurricanes, earthquakes, natural subsidence and cavern collapse) on SPR facilities.

A number of previous reports have been prepared on the Bayou Choctaw site during the course of the SPR program. It is the intention of this report to present a comprehensive document of the geologic characterization of the Bayou Choctaw salt dome rather than "redo" or summarize the previously prepared documents. The majority of work presented here has been developed as part of this study. Since no field work was performed as part of this Phase I program, all data interpretation has been based on materials collected from other sources. Certain interpretations have been identified throughout the text in those areas where insufficient data is available.

The characterization has emphasized the interpretation of the geology and geometry of the Bayou Choctaw salt dome. Only minimal effort has been directed at those technical and non-technical items that were considered to have no direct impact on the oil storage and containment at the site. We therefore refer the reader to previous reports addressing other areas of concern (See Section 8).

The report has five technical sections. Section 3 presents the geologic setting of Bayou Choctaw; Section 4 presents the surface and near-surface geology and includes the hydrology above the caprock; Section 5 addresses the caprock geology; Section 6 discusses the salt dome and includes domal uplift, dome geometry, faulting, and cavern geometry; and Section 7 discusses hazards that could effect the SPR facilities.

This report has been prepared in association with Dr. T. R. Magorian, Geologic Consultant. Dr. Magorian provided full-time project assistance throughout the contract period. Mr. C. Smith, Consulting Groundwater Hydrologist, also provided assistance in the data collection and interpretation effort of the project.

2.2 - Location

The Bayou Choctaw site is located in the south-central part of Louisiana approximately I3 miles southwest of Baton Rouge and approximately 5 miles west of the Mississippi River (Figure 2.1). Specifically, the dome is located in Sections 52, 53, 60 and 61 of Township 9 South, Range 11 East and in Sections 28 and 29 of Township 8 South, Range 11 East in Iberville and West Baton Rouge Parishes as shown on the site topographic map (Figure 2.2). This map shows the relation of the site to the Mississippi River on the east and the backswamps of the Atchafalaya basin on the south and west. The site is accessible by road from Route 1 or by canals excavated across the dome from Choctaw Bayou (Figure 2.3).

2.3 - Man's Activities

The Bayou Choctaw dome, as many others in the Gulf Coast region, was discovered by the Gulf Oil and Refining Corporation's seismographic parties in 1926. Shortly after discovery, the sulfur rights to the dome were obtained by the Texas Gulf Sulphur Company. Texas Gulf Sulphur Company completed drilling six wells in 1930 and two wells in 1931, but no sulfur was found. The oil drilling rights were then obtained by the Standard Oil Company of Louisiana.

The first well completed by Standard Oil was Gay Union Corporation No. 1 drilled in 1931 which produced 500 barrels of oil per day. Subsequent to that time, over 300 wells have been drilled by various companies on or around the Bayou Choctaw dome for development of oil and gas. Peak oil production from the dome was from the late 30's through the early 50's. Oil is still being extracted from around the dome; however, production has declined to less than 100,000 barrels per year.

In 1934 Allied Chemical Corporation (formerly Solvay Process Company), purchased the property over dome and commenced drilling for brine development. Since 1934 Allied has drilled over 20 brine wells on the dome. Discussions and figures showing these caverns are presented in Section 6 of this report. Allied's method of brine operation was for rapid extraction of brine with minimal attempt made to control the shape or size of the caverns. As a result, several of the caverns were solutioned to the caprock resulting in leakage and ultimate abandonment. This uncontrolled brining method resulted in the collapse of Cavern 7 in January, 1954. The failure of this cavern was catastrophic, resulting in a large area of ground subsidence and the formation of Cavern Lake.

The results of man's activities at the Bayou Choctaw salt dome are presented in Figure 2.3. This map shows the site boundaries and cavern locations, as well as, oil and gas leases in the area of the dome. Depth contours at 2,500 and 4,500 feet on the salt surface are shown for reference. The surface entry location of all caverns is shown on the figure.

For caverns which have been sonar surveyed, the outline of the maximum cavern diameter is shown. This outline is a composite of the largest cavern diameters, taken at 10 foot intervals over the length of the cavern; it is not the maximum cavern diameter for a particular depth in the cavern. Cavern geometry is discussed in detail in Section 6.7.

The surface locations of all known wells drilled over and around the dome are indicated and, if verticality survey data was available, the bottom hole location is shown. Wells with no verticality data were assumed to be vertical. An unsurveyed hole may deviate up to 2.5° from the vertical. Wells which penetrate salt are differentiated from other wells.

Wells are identified by a letter and numerical designation, which represent the well operator and the actual well number. A hyphenated well number refers to a side-tracked hole. The well identification is generally unique only within the particular lease in which it is found. The lease is identified by the lessor's name (for example, Gay Union Corporation or Wilbert's Myrtle Grove). Wells identified with the letter F were numbered sequentially by the Feeport Oil Company irregardless of the lease; however, the remaining wells were numbered in sequence by the operators only within one lease. For this reason, there are, for example, two C 1 wells -- one in the Gay Union lease and the other in the Morley Cypress lease.

In 1976 the DOE purchased part of the Bayou Choctaw salt dome from Allied Chemical Corporation for the SPR storage program. Included within this property, shown on Figure 2.3, are 11 caverns of which Caverns 15, 18 and 19 are currently being used for oil storage. Cavern 15 contains approximately 13 million barrels of oil and Caverns 18 and 19, 4 million and 5 million barrels, respectively.

Other caverns currently in use on the dome are Allied's Cavern 17, being used for high pressure ethane storage and brine enrichment, and Cavern 16, for brining and ethane storage. Allied has drilled wells 24 and 25 in the southern portion of the dome for future development of brining operations.

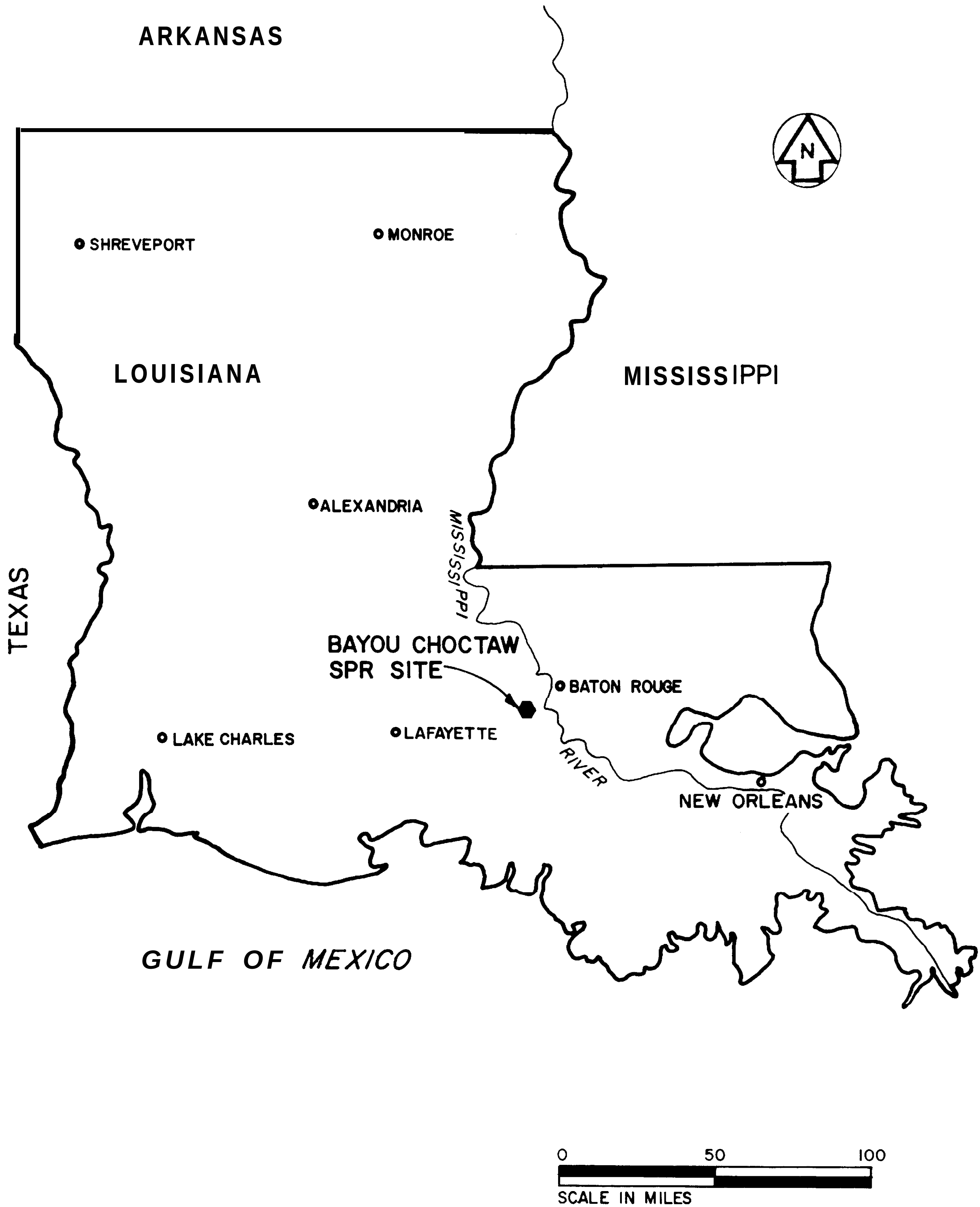
The DOE is currently in the process of selecting and developing a new cavern to be used as a replacement for the ethane storage Cavern 17.

2.4 - Method of Study

The interpretation of the geology and geometry of the Bayou Choctaw salt dome has been based entirely on available geophysical log data obtained in test wells over and around the dome. No seismic reflection or refraction work has been performed on or near the dome to provide any additional information.

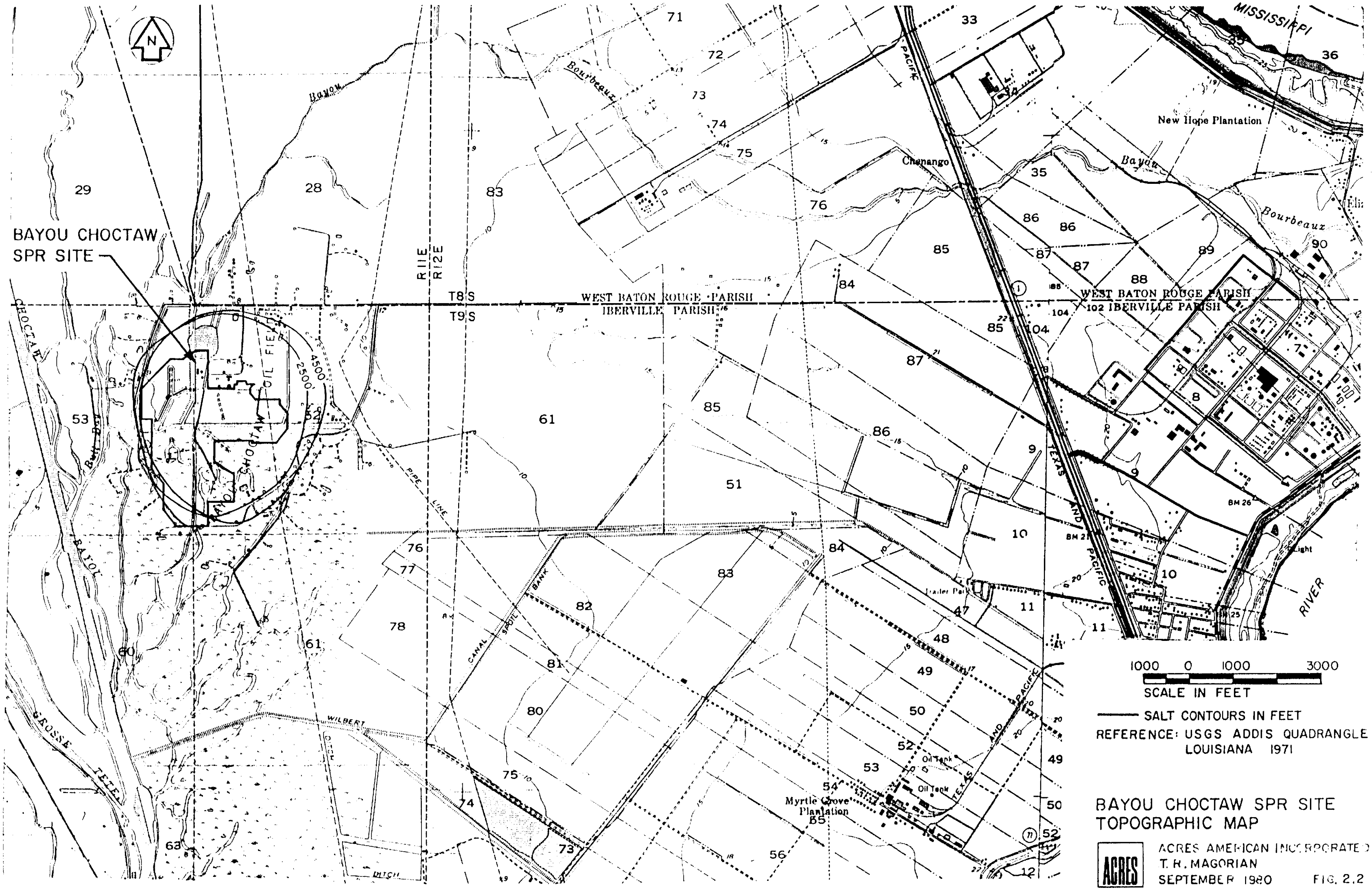
The gamma-ray logs provided the best information; however, the limited number of these logs in the area has required the principal use of the electric log for interpretation. The salt may include thin or minor anhydrite which cannot be discriminated without the use of radioactivity or sonic log data. A few driller's logs were used for interpretation of the dome; however for the most part, these wells were not drilled to depths that could provide much worthwhile data applicable to the storage program. The well logs were used to interpret and correlate key stratigraphic marker horizons around the dome. These units are discussed in detail in Sections 4, 5 and 6.

A total of twenty-eight holes have been drilled into the salt on top of the dome for brine or storage, while 73 more wells, drilled on the sides of the dome, penetrated salt. Of the 350 additional oil and gas wells drilled around the dome, 50 were drilled to within 100 feet of the salt. The extensive well drilling around and on the dome has afforded excellent control in defining the salt dome geometry, structure and stratigraphy of the site area. The sections and structure and isopach maps presented in this report have been based on more than 150 control points.



BAYOU CHOCTAW SPR SITE
SITE LOCATION MAP

ACRES AMERICAN INCORPORATED
T. R. MAGORIAN
SEPTEMBER 1980 FIG. 2.1



BAYOU CHOCTAW SPR SITE
TOPOGRAPHIC MAP

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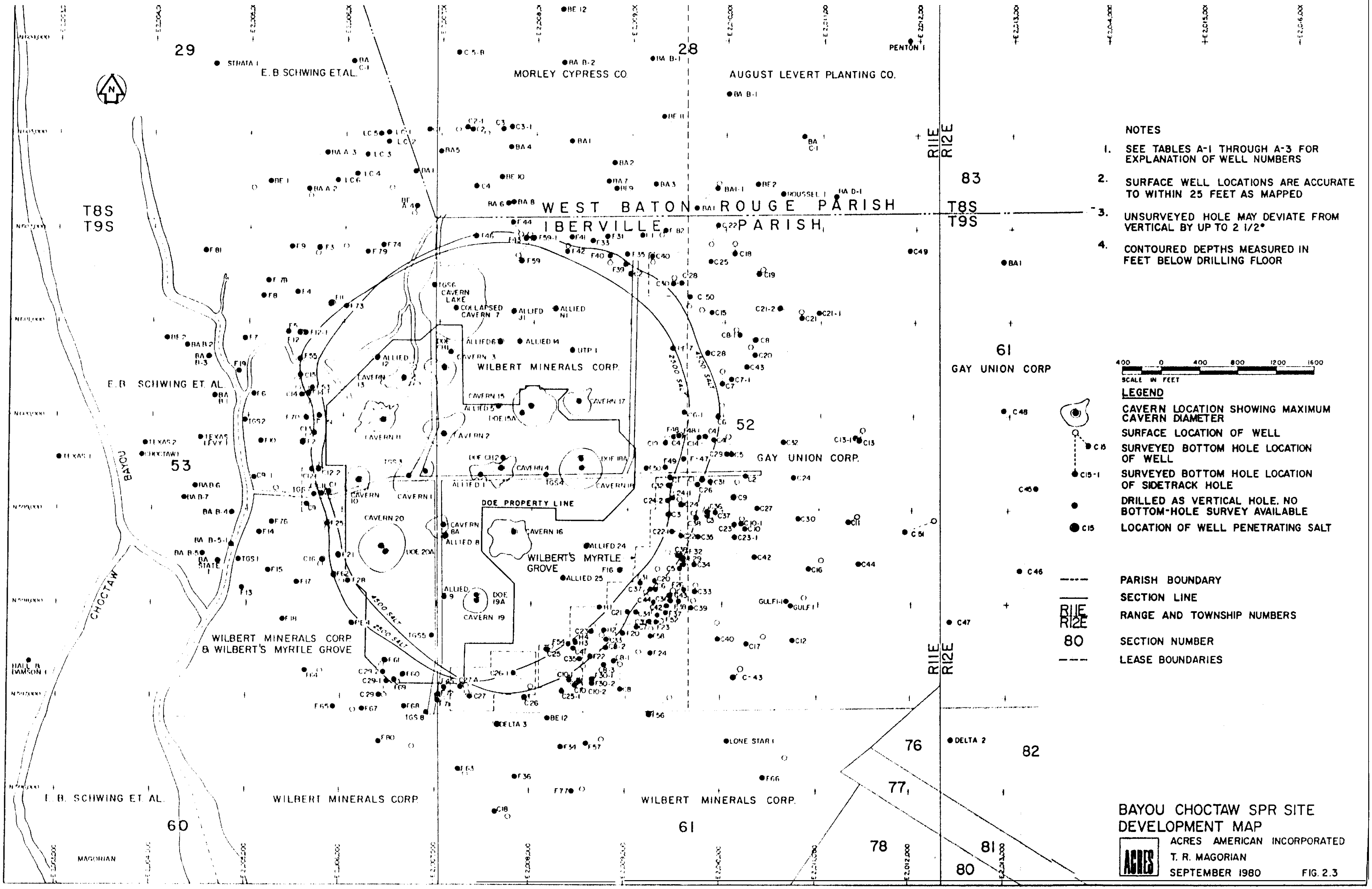
FIG. 2.2



BAYOU CHOCTAW SPR SITE DEVELOPMENT MAP

3 - REGIONAL GEOLOGY

3.1 - Geologic Setting

The Bayou Choctaw salt dome lies within the Gulf Coast geosyncline, an area of sediment deposition from the Mesozoic era to the present. Table 3.1 is a geologic time chart showing the breakdown of geologic time into eras, periods and epochs. In the site area, the geosyncline contains up to 30,000 feet of silts, sands, shales, limestones and evaporites. These sediments were deposited in a variety of sedimentary environments including desert basin, evaporting flat, ocean basin and delta.

Salt domes within the geosyncline occur in two regions: a northern belt through northern Louisiana and Mississippi, and a southern belt along the Gulf Coast and offshore. These two belts are shown on the regional tectonic map (Figure 3.1). The Bayou Choctaw dome is on the northern edge of the southern coastal belt of salt domes.

The largest tectonic feature near the site is the Baton Rouge fault system which lies approximately five miles to the north (Figure 3.1). The fault trends from Breton Sound, Louisiana, to Matagorda Bay, Texas, a distance of more than 500 miles. In Louisiana the Baton Rouge fault marks the northern limit of the southern Gulf Coast salt domes.

3.2 - Geologic History

The major sedimentary and orogenic events that affected the Bayou Choctaw area are discussed in this section. A detailed summary of Gulf Coast stratigraphic units from the Paleozoic through early Cenozoic is given in Table 3.2. Stratigraphic units from the middle and late Cenozoic are discussed in Section 6, Tables 6.1 and 6.2. The information on these tables, except for the Paleozoic through early Cretaceous, is based on the interpretation of electric logs from wells just north of the Bayou Choctaw dome (these wells are shown on Figure 3.2). The Paleozoic through early Cretaceous data is from published sources. The major units of the middle Cretaceous to Eocene were drilled in the False River gas field 15 miles north of Bayou Choctaw. Wells at Bayou Choctaw have been drilled only as deep as the Oligocene. Major stratigraphic changes probably occur across the Baton Rouge fault between the units shown in Table 3.2 and those surrounding the site.

3.2.1 - Paleozoic Era

No Paleozoic rocks are exposed within the state of Louisiana. Geophysical evidence and drilling data indicate that continental Paleozoic basement underlies the northern and central sections of the state. Recent interpretation of the geophysical data indicate that the southern part of Louisiana is underlain by oceanic basalts of Mesozoic age (see Section 3.2.2). The exact location and nature of the contact between the continental and oceanic basements is uncertain but is believed to be expressed in the overlying sediments as the Baton Rouge fault. If this is the case, the Bayou Choctaw site is approximately over the contact area. Depth to basement, either continental or oceanic, is approximately 30,000 feet.

3.2.2 - Mesozoic Era

The geologic history of the Gulf Coast geosyncline began with the opening of the Atlantic Ocean in the Triassic. Before the Americas separated from Africa, the land mass of the present states of Alabama and Georgia was adjacent to Venezuela and Brazil (the Flordia peninsula was not formed until the Cretaceous). With the opening of the continents, the gap between the Americas began to fill with oceanic basalts and later with sediment. The Sigsbee Deep, a large depositional basin in what is now the Gulf of Mexico, apparently formed at this time. This major orogenic episode was followed by a long period of quiescence in the early Jurassic during which time the thick sequence (1,000 to 5,000 feet) of Louann evaporites (salt and anhydrite) were deposited. Following the deposition of the Louann evaporites, the principal sediments deposited in the Gulf Coast geosyncline were clastics and carbonates of late Jurassic and early Cretaceous age.

The Mesozoic section consists of sedimentary rocks deposited during cycles of alternating marine transgression and regression. These sequences of different sediments form the basis for the Gulf Coast stratigraphic divisions as shown in Table 3.2. The depths of these sediments range from 18,000 to 30,000 feet near the site.

The first movement of the salt occurred in either the late Jurassic or Cretaceous. The movement probably formed a ridge running northwest-southeast parallel to the Baton Rouge fault (see Section 3.3).

3.2.3 - Cenozoic Era

The base of the Cenozoic section, as shown by the drilling at False River, is marked by the first dark phosphatic shales overlying Cretaceous chalk.

During the Eocene, the westward-drifting North American continent collided with the East Pacific Rise. This Laramide orogeny caused the formation of the Mexican volcanoes and the Rocky Mountains. The erosion of these uplifted areas resulted in large amounts of sediments being deposited in the Gulf basin. The initial sediments representing the Laramide in the southern Louisiana area are the sands of the Wilcox Formation (Table 3.2).

The thick Gulf Coast sedimentary deposits are the best known North American example of an active geosyncline. The geosyncline has continued to subside under the accumulated weight of sediments from the Eocene to the present. Lighter rocks such as salt and geopressured shale, rise from salt ridges in the form of domes and diapirs. Sediment accumulation is localized by down-to-the coast growth faults like the Baton Rouge fault, which forms the northeast edge of the recent backswamps, levees and deltas. The shallow beds dip towards the Gulf, with dip and structural complexity increasing with depth. These formations represent alternating transgressions of thick marine shale wedges and regessions of deltaic sands with interbedded lagoonal or backswamp muds. The deltaic stratigraphy is complex in detail with unconformities and local sand lenses. Stratigraphic correlations are difficult, as would be expected, in this complex delta environment.

3.3 - Regional Faulting

Faulting in the Gulf Coast region occurs at two scales: large-scale regional faulting associated with basin filling, and small-scale, localized faulting associated with the upward movement of salt domes. The regional faults can be mapped for miles and have displacements on the order of hundreds to thousands of feet while the faulting associated with salt domes is restricted to the immediate dome area and seldom extends more than a few miles from the dome. Displacements of domal faults are on the order of tens to hundreds of feet. This section addresses the regional faulting in proximity to the Bayou Choctaw site while a detailed discussion of dome-related faulting is presented in Section 6.

As previously stated, the Bayou Choctaw salt dome is located within the Gulf Coast geosyncline, a region typified by large-scale, east-west trending normal faults (Figure 3.1). The faults are generally parallel to the present Gulf Coast or parallel to one of the older Gulf Coast geosynclinal axes which are subparallel to the present coast. These faults are frequently referred to as "growth" faults since their origin was caused by the long-term and continuing subsidence of the geosynclinal basin. Gulf Coast growth faults are downthrown to the south in the direction of the major area of basin filling. The larger structures may have up to five miles of fault displacement. The faults dip at approximately 60" in the near surface sediments but tend to flatten out at depth. Regional growth faults in the Bayou Choctaw area are the Baton Rouge and West Addis, north of the site, and the Bayou Plaquemine to the south of the site. These faults are shown on the regional geologic map (Figure 3.2), which is a contour map of the top of the Miocene "A" Sand (see Section 6).

The Baton Rouge fault lies 5 miles to the north of the site at the surface and is estimated to pass beneath the site at depths between 30,000 to 50,000 feet. This normal fault dips toward the Gulf and has a displacement of up to 25,000 feet.

The West Addis fault parallels the Baton Rouge fault and, at the surface, lies 4 miles north of the Bayou Choctaw site. The fault is parallel to the flat north side of the dome (Figure 3.2) and may have had some influence on the shape of the dome. The fault plane dips toward the dome; however, any intersection of the dome with the fault is below the depth of present well data.

TABLE 3. I

BAYOU CHOCTAW SPR SITE
GEOLOGIC TIME TABLE

ERA	PERIOD	EPOCH	GLACIATION	INTERGLACIATION	MILLIONS YEARS AGO
CENOZOIC	QUATERNARY	HOLOCENE			0.012
		PLEISTOCENE	WISCONSIN IAN		
				SANGAMON IAN	0.215
			ILLINOIAN		
				YARMOUTHIAN	0.70
			KANSAN		
				AFTONIAN	1.3
			NEBRASKAN		
				(BLANCAN ?)	1.8
	TERTIARY	PLIOCENE			10
		MIOCENE			22.5
		OLIGOCENE			40
		EOCENE			55
		PALEOCENE			70
MESOZOIC	CRETACEOUS				141
	JURASSIC				195
	TRIASSIC				230
PALEOZOIC					

REFERENCE: VAN EYSINGA , 1975

TABLE 3.2

BAYOU CHOCTAW SPR SITE
PALEOZOIC, MESOZOIC AND EARLY CENOZOIC GEOLOGIC UNITS

Age	Formation	Stratigraphic Unit	Biostratigraphic Zone	Sediment Type	Depositional Environment	Transport Mode	Related Structure/Thickness	Depths to Top: High on Dome (ft)	Depths to Top: Away from Dome (ft)
EOCENE	Jackson	Yazoo	Late	Black shale	Pelagic/ocean floor	Organic bloom	Forms most of shale sheath, extruded with salt	Sheath	
	Yegua	Cockfield	Upper	Black shale	Pelagic/ocean floor	Suspension & bloom	Thin turbidite sand at top	Not penetrated	10,000 at False River
	Wilcox	Middle	Globorotalia rex	Sands	Delta	Fans from Laramide uplift of Rocky Mountains		Not penetrated	11,200 at False River
PALEOCENE	Midway	?	Danian	Black shale	Restricted Pelagic	Suspended/organic	Not known	Not penetrated	3,400 at False River
CRETACEOUS	Gulf	Austin-Taylor - Navarro	Senonian	Chalk	Pelagic	Clear water - open ocean	Stable carbonate shelf	Not penetrated	16,000 at False River
		Eagle Ford	Turonian	Black shale	Pelagic	Suspended/organic	Easily overpressured	Not penetrated	18,100 at False River
		Woodbine/ Tuscaloosa	Cenomanian	Green sand	Delta	Beach/Marine bar	Deep gas fields being developed (see Note 1)	Not penetrated	19,200 at False River
	Comanche	Glen Rose	Albian-Aptian	Anhydrite, sand	Desert flat	Alluvial & evaporite	Black shale at top	Not penetrated	Not penetrated
	Coahuila	Travis Peak	Neocomian	Red shale	Desert	Alluvial fans	Not known	Not penetrated	Not penetrated
JURASSIC	Cotton Valley		Portlandian-Kimmeridgian	Shale & arkrose	Nonmarine fan and basin	Desert wash	2,500 ft thick	Not penetrated	Not known
	Buckner		Oxfordian	Anhydrite	Evaporating flat	Seawater incursions	1,000 ft thick	Not penetrated	Not known
	Smackover		Dogger	Limestone	Reef	Clear water	800 ft thick	Not penetrated	Not known
	Norphlet	Louann	Lias	Salt - originally 7,500+ ft thick, overlies Werner Anhydrite	Playa flats	Seawater incursions	Domes develop with overburden, probably salt bulge at toe of shelf (see note 2)	613	Approx. 23,000 under site 37,000 under geosyncline
TRIASSIC	Eagle Mills	Newark	Rhaetian	Red shale, basalts	Desert basin (like Red Sea area today)	Alluvial fans	Faulted half-grabens of mid-Atlantic ridge; diabase intrusions over 7,000 ft in Arkansas (see note 3)	Under salt	
PALEOZOIC	Basement	Not known	More than 230 million years ago	Possibly schist as seen in nearby Florida	Not known	Not known	Only present under Baton Rouge Fault	Under salt	Approx. 30,000 ft

NOTES:

(1) This section thins southward as shown on regional seismic profile presented by Chevron USA at Louisiana Conservation Commission hearings defining the unitization limits of the False River gas field and 1,280 acre well spacing.

(2) The top is over 17,000 feet deep in drill holes. A continuous bed of Louann salt once underlay the Gulf region, including the Gulf of Mexico. A single salt basin covered an area extending all the way to Tabasco. Domeless areas which separate the salt dome basins and such major tectonic features as the Monroe uplift, and Jackson dome are covered in part by at least a thin veneer of Louann salt.

The Louann was deposited in a closed desert basin or playa, like the Red Sea, along the west side of the still narrow Atlantic. Rifting of the Caribbean opened the Gulf of Mexico to separate Tabasco or Isthmian salt basin of Mexico.

(3) Southern edge of North American continent, as represented by the Baton Rouge fault, dips south under the site.

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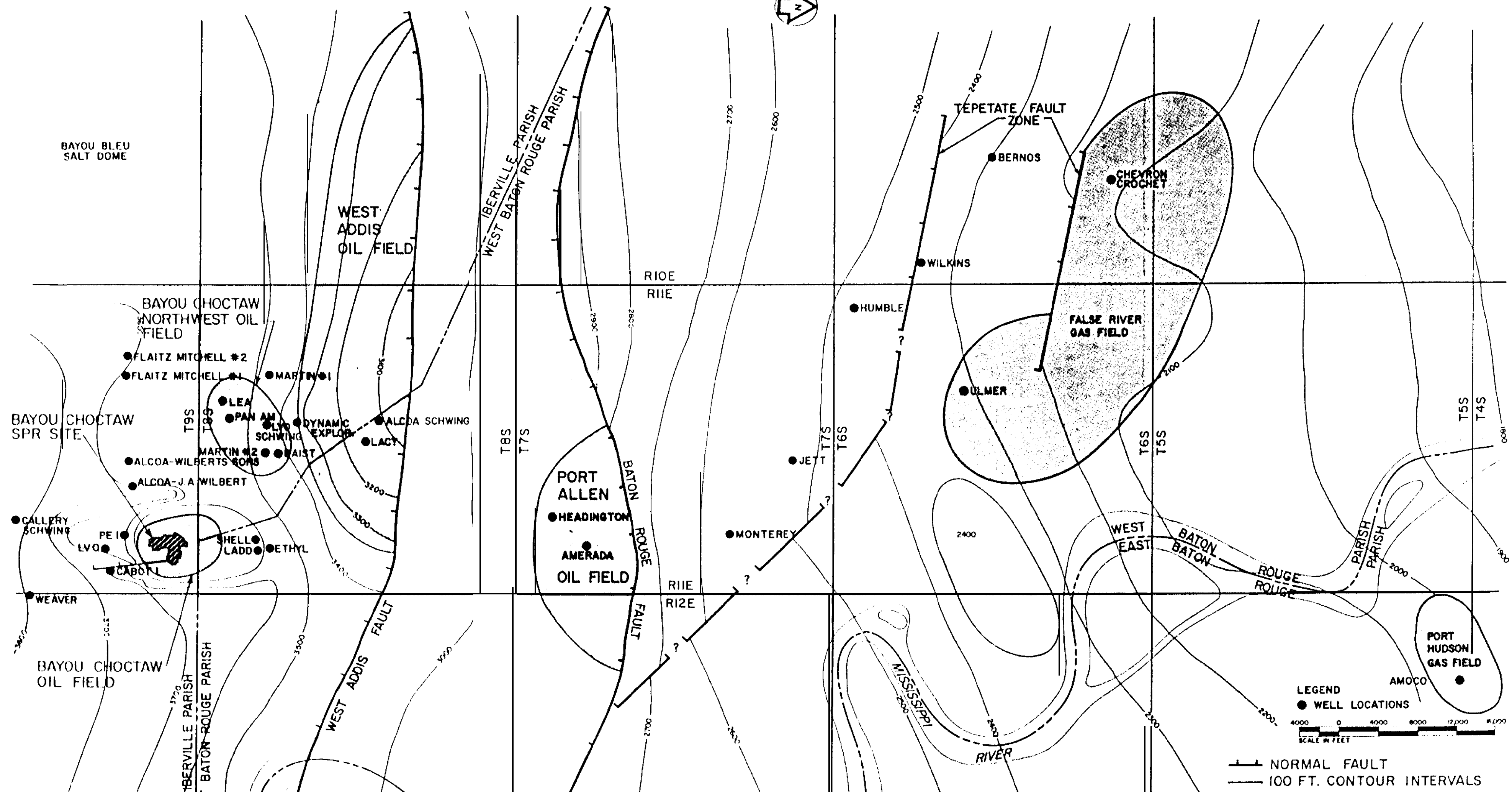

BAYOU CHOCTAW SPR SITE
REGIONAL GEOLOGIC MAP
(TOP OF "A" SAND)

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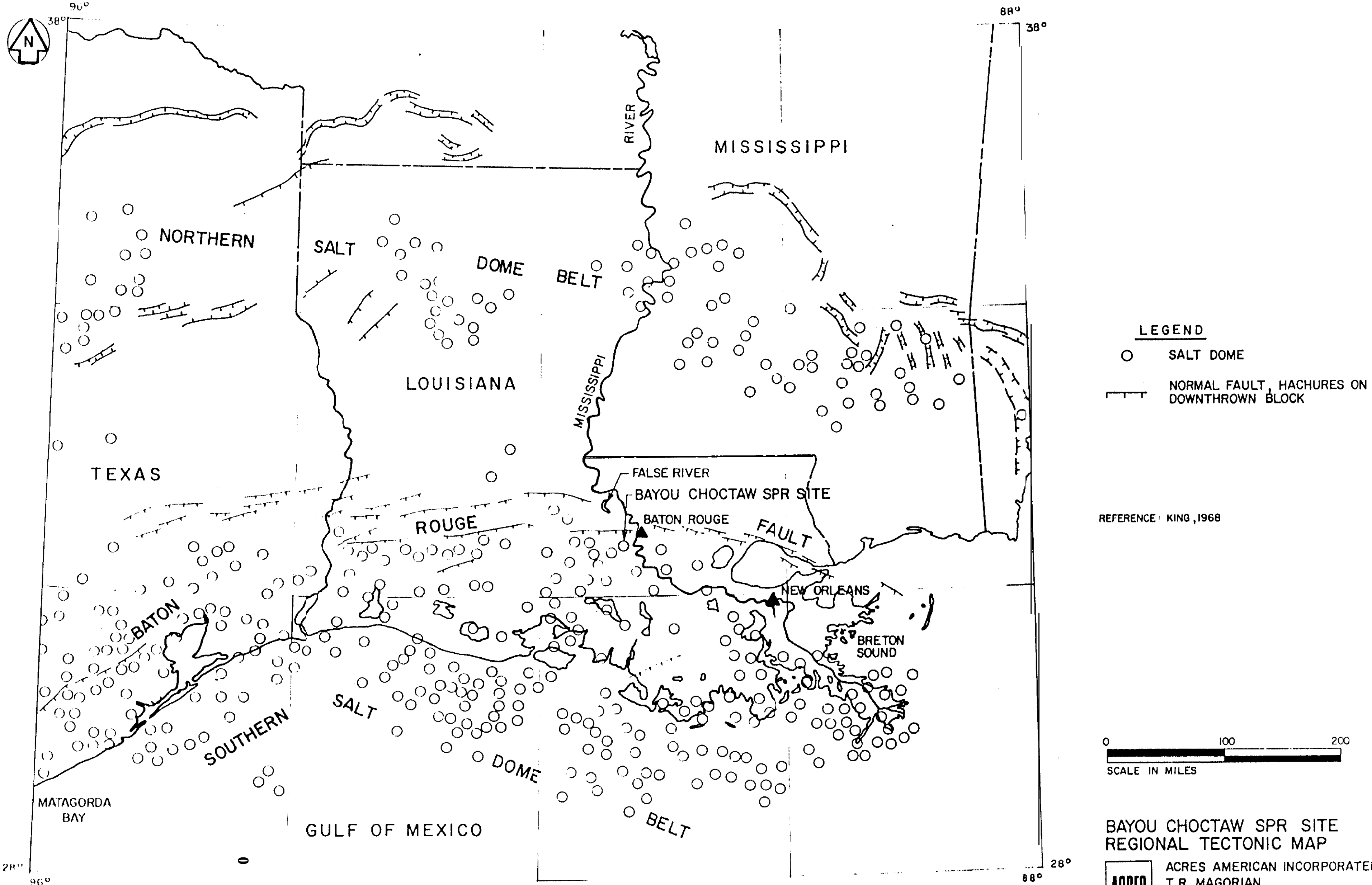
T. R. MAGORIAN
SEPTEMBER 1980 FIG. 3.2



BAYOU CHOCTAW SPR SITE
REGIONAL TECTONIC MAP

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FIG. 3.1

4 - SURFACE AND NEAR-SURFACE GEOLOGY

4.1 - Introduction

The surface and near surface geology at Bayou Choctaw consists of Pleistocene through Holocene sediments. These unconsolidated sediments thin from a thickness of approximately 1,000 feet away from the dome to about 400 feet over the top of the dome. The units were mapped using well logs and samples. A sample electric log showing the interpretation of the near surface sediments is included as Figure 4.1. The logs were used to determine lithology and water quality. Formation names are based on regional correlations.

The State of Louisiana requires the top 100 feet of gas and oil wells to be cased to prevent contamination of near surface aquifers. Because of this requirement, wells can be logged only below this depth. However, several shallow borings (PB/KBB, 19784 and 1978h) have been drilled in the site area and form the basis of the stratigraphic data for the upper 100 feet of sediments. Based on all of these data, two geologic cross-sections trending northeast-southwest and northwest-southeast across the site were constructed (Figures 4.2 and 4.3). A key to the geologic symbols on these and other figures is shown on Table 4.1.

4.2 - Stratigraphy

The Pleistocene through Holocene sediments overlie Tertiary deltaic deposits which have been accumulating in the Gulf Coast geosyncline and are approximately 400 to 1000 feet thick over the site. These sediments are related to recurring periods of glacial advance and retreat. During periods of glacial ice accumulation, sea levels were lowered and the Mississippi River cut into the older sediments. As the glaciers melted, sea levels rose, resulting in the deposition of sands and gravels in the valleys cut during the preceeding glacial stage. During interglacial periods, the carrying capacity of the Mississippi decreased as the glaciers melted and sea level rose, causing a decrease in sediment grain size to silt and clay (Bernard and LeBlanc, 1965). These coarse-fine cycles can be seen on the two geologic cross-sections.

The oldest Pleistocene deposits are proglacial sediments of Kansan and Nebraskan age. They are the undifferentiated sediments of the Williana-Bentley Formation which consist predominantly of sands and gravels with some clay layers. This unit is not present over the dome, but occurs at depths of approximately 900 feet surrounding the dome. The Williana-Bentley thickens to 150 feet away from the dome (Figures 4.2 and 4.3).

An unnamed clay of Yarmouthian age (Table 3.1) overlies the Williana-Bentley Formation. The clay was deposited as an interglacial backswamp sediment. Away from the dome, this unit lies at a depth of approximately 650 feet.

Over the dome, it was found to overlie the caprock in two wells, J 1 and N 1, at depths of 477 and 500 feet, respectively. The clay thickens to between 250 and 300 feet away from the dome (Figure 4.2 and 4.3). It is likely that the clay and gypsum caprock unit, which is discussed in Section 5, is composed of a considerable amount of this clay unit.

The Gonzales Sand is a thick sequence of sands deposited by the glacial meltwaters during the Illinoian interglacial. Sand and gravel with minor silt and clay were deposited by coalescing point bars as the Mississippi River meandered across its channel. Clayey or silty layers accumulated near the top of the Gonzales as the Mississippi neared its base level. The Gonzales has not been completely pierced by the salt dome. The unit thins to 130 feet over Cavern 2 and thickens to 350 to 400 feet away from the dome (Figure 4.3). Samples from Core Holes 1 and 2 (PB/KBB, 1978c) indicate that the Gonzales is predominantly a coarse to fine quartz sand with occasional organic matter and shell fragments. The base of the Gonzales is the base of the Plaquemine Aquifer (see Section 4.3.2).

The Prairie Clay was deposited over the Gonzales during the Sangamonian interglacial period while the Mississippi was at base level. The formation is a backswamp deposit of clay and silt. The Prairie is of uniform thickness between 40 to 60 feet over the dome and thickens to 80 feet away from the dome. The effects of domal uplift are evident on the Prairie. The Prairie is at a depth of nearly 150 feet in wells F 28, DOE 20A and Cavern 8A overlying a caprock high (Figure 4.3). Away from the dome, the Prairie is generally at a depth of about 200 feet.

Overlying the Prairie is a proglacial sand of Wisconsinian age. This sand, here referred to as the Shallow Plaquemine, was deposited in an environment similar to that of the Gonzales Sand. Samples from shallow borings indicate that the Shallow Plaquemine is a coarse to medium, dense, gray, quartz sand with layers of silt and clay and occasionally organic matter. The thickness of the unit is difficult to determine because of the lack of data at shallow depths.

On the cross-sections, it appears that the Shallow Plaquemine varies from 100 to 150 feet thick and is thinnest over the west flank of the dome. The top of the unit is assumed to be at a depth of 60 feet both away from and over the top of the salt dome.

The Atchafalaya Clay (Topstratum of Fisk, 1944) overlies the Shallow Plaquemine. The unit is a Holocene, post-glacial backswamp sediment deposited as the Mississippi reached base level after the Wisconsinian glacial epoch. Samples from shallow borings indicate that the unit is predominantly a soft gray clay with minor silt layers and pockets and layers of wood and other organic matter. Ferrous nodules are found near the surface. The Atchafalaya is approximately 60 feet thick and lies at the surface over much of the area. River flood waters left thin sand layers at the top of the unit.

The effect of dome growth on sedimentation can be seen on the cross-sections. All of the Pleistocene units are thinner or absent over the dome and thicken away from the dome. Some of the units missing over the dome may have been incorporated into the caprock.

4.3 - Geohydrology

This section addresses the geohydrology on and around the Bayou Choctaw salt dome for the purpose of defining the groundwater regime as it relates to dissolutioning of salt from the dome. The geohydrology of the dome was assessed from published literature, interpretations of selected geophysical well logs and discussions with Mr. C. Smith, Consulting Groundwater Hydrologist.

4.3.1 - Regional Groundwater Conditions

At Baton Rouge where the Mississippi River crosses the Baton Rouge fault, the river changes from being erosional, north of the city, to depositional, south of the city. At approximately the same location, the groundwater flow changes from being influent to the river north of Baton Rouge to being effluent from the river south of the city. In the vicinity of Bayou Choctaw, the river is effluent from its river channel between the levees to the Atchafalaya river during the spring high stage period while during the low stage period during the fall, the flow is reversed.

In the city of Baton Rouge, the principal aquifers are the "2,000" and "2,800" foot sands. These are of Miocene age and are comparable to the "A" and No. 1 Sands in the Bayou Choctaw area. The Baton Rouge fault, downthrown to the south, acts as a hydraulic barrier to the saline waters in the region as shown in Figure 4.4. This figure shows the contact between slightly and moderately saline groundwater (1,000-3,000 mg/l and 3,000-10,000 mg/l dissolved solids). Freshwater is defined as having less than 250 mg/l dissolved solid. In the Baton Rouge area, this contact is at a depth of approximately 2,000 feet while south of the Baton Rouge fault, the contact rises sharply and in the Bayou Choctaw area is at a depth of about 400 to 500 feet. Monitoring of wells in the Baton Rouge area is underway to determine the possibility of saline water migration from south of the fault into the industrial and potable water supplies of the city. Evidence to date indicates that the fault is a significant hydraulic barrier that precludes this from happening.

In the Bayou Choctaw area, the principal aquifer is the Plaquemine Aquifer in sediments of Pleistocene age. The aquifer is an alluvial deposit of the Mississippi River and has a thickness of about 200 feet.

4.3.2 - Groundwater in the Bayou Choctaw Area

Atchafalaya Clay

The Holocene Atchafalaya Clay was deposited under backswamp conditions and consists of highly plastic clays with occasional peat and silt layers. No data on the clay conditions at the site were available, but the results of a geotechnical investigation for Atchafalaya levee construction are reported by Foot and Ladd (1977). These investigations show the clay to have a moisture content generally of 40 to 70 percent with occasional values over 140 percent. The deposit is normally consolidated with some slight over-consolidation at some horizons. The clay is much more impermeable than the underlying Plaquemine Aquifer, and hence acts as a confining stratum. The extent of the clay at the site is shown on the sections, Figures 4.2 and 4.3.

Plaquemine Aquifer

The Plaquemine Aquifer is composed of sediments of Pleistocene age and is made up of two units. The upper Shallow Plaquemine Aquifer unit is a sand of probable Wisconsinian age. The lower aquifer, which is laterally equivalent to the Gonzales Sand, is of Illinoian age. These units are separated by the Prairie Clay (Sangamonian age). This clay is laterally discontinuous, which makes the Shallow Plaquemine and Gonzales hydraulically connected (Smith 1976). The Mississippi River channel is downcut through the Atchafalaya Clay and hence is in direct hydraulic connection with the Plaquemine Aquifer. Thus changes in river stage are reflected by changes in water levels within the aquifer. At the Bayou Choctaw site, the piezometric head in the aquifer rises to elevation +15 feet during the high river stage with flow towards the Atchafalaya and drops to +5 feet during low river stage with flow towards the Mississippi.

From the numerous wells extending into the Plaquemine Aquifer in the Iberville Parish area, the coefficient of permeability is estimated to be in the range 1,900 to 2,500 gallons per day per square foot (Whiteman, 1972).

The results of chemical analyses on the water from wells in the Iberville Parish have been recorded by Whiteman (1972). The relationship between the specific conductivity, total dissolved solids [TDS], and the chloride content are shown in Figure 4.5. The relationship between total dissolved solids and specific conductivity is given by:

$$\log [TDS] = 0.97132 \log K_0 - 0.14676$$

where [TDS] = total dissolved solids concentration, ppm

K_0 = specific conductivity corrected to 25°C, micromhos/cm

The chloride contents for the water samples indicate two distinct populations: Group A and Group B (Figure 4.5)

The presence of ions other than Na+ and Cl^- (for example, Ca^{++}, Mg^{++} SO_4^{--}, CO_3^{--}, HCO_3^-) results in departure from the NaCl line, The specific conductivity of 800 micromhos/cm corresponds to a field formation resistivity of 25 ohms m^2/m at 25°C. The Group A data points lying above the line are obtained from waters with a high chloride content. The Group B points are from shallower waters with chloride content up to 40 ppm. The groups indicate different chemical compositions and a general lack of mixing of the two types of water. The saline waters are, thus, relatively stable and immobile compared to the shallower fresh water.

The elevation of the fresh water/saline water interface around the dome is at approximately 400 feet as shown in Figures 4.2 and 4.3. For the purpose of this report, the saline water has been defined as field formation resistivity less than 25 ohms m^2/m.

The Plaquemine Aquifer is underlain by a series of clays and sands of early Pleistocene age. These are all saline in the vicinity of the salt dome.

4.3.3 - Salt Dissolution

Salt dissolution has been estimated based on the simple one dimensional model described by Glasbergen (1979). This consists of diffusion through the caprock and dispersion under flow conditions in the overlying sandy sediments. The model is shown diagramatically in Figure 4.6. This model assumes static water in the caprock and does not include thermal effects on flows resulting from higher temperatures above the salt compared to the surrounding sediment, or density effects from salinity variations. The estimated dissolution rates will therefore be lower than if these additional mechanisms were included. Two dimensional models for salt dissolution and for flow around salt domes have been developed (for example, Peck et al, 1979 and Gnirk, 1979) which include the effects of heat and density variations. For the 1-D model the calculated rate of dissolution is primarily a function of the rate of diffusion through the caprock. For one-dimensional diffusion:

$$\frac{\partial C}{\partial t} = D \frac{\partial^2 C}{\partial z^2}$$

where: D = bulk diffusion coefficient
C = concentration
z = coordinate direction
t = time

The bulk diffusion coefficient includes the effect of the porous medium in reducing the diffusion coefficient compared to the species in water. For steady state conditions, the above equation reduces to:

$$Q = DiA$$

where: Q = concentration flux
i = concentration gradient
A = area of diffusion

Data on the diffusion coefficient for the caprock does not exist for this site. Freeze and Cherry (1979) indicate that the diffusion coefficient for ionic species in water is 1 - 2 x 10^{-9} m^2/s. Bulk diffusion coefficients of the same species in porous media range from 1 x 10^{-10} to 1 x 10^{-11} m^2/s. Glasbergen (1979) employs a value of 7.9 x 10^{-10} m^2/s.

The concentration gradient above the caprock has been calculated from resistivity logs. In the sands immediately above the saline zone, the concentration is approximately 30 ppm. At the caprock/salt interface, it is assumed that saturated brine conditions occur and the concentration would thus be approximately 300,000 ppm. For a caprock thickness of 150 feet, a salt dissolution rate of about 4 x 10^{-3} mm/yr (1.6 x 10-5 in/yr) is estimated. Salt dissolution by this mechanism is thus not significant in terms of the life period expected for the facility. It is probable that during periods when sea level was relatively depressed, the fresh water layer would have extended deeper around the dome. Under these conditions, dissolution could have occurred at a faster rate than is indicated by the above calculations.

4.3.4 - Summary

The geohydrology of the area is summarized by the following:

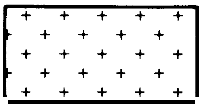
- the extensive groundwater extraction in the area of Baton Rouge appears to be isolated from the Bayou Choctaw area by the Baton Rouge fault;

- the fresh water/saline water interface in the Bayou Choctaw area occurs in the Plaquemine Aquifer at a depth of 400 to 500 feet;

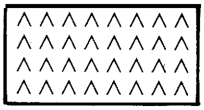
- groundwater flow in the Plaquemine Aquifer varies depending upon the stage of the Mississippi River away from the river during periods of high stage and towards the river during periods of low stage; and

- Salt dissolution rates calculated using a simple diffusion/dispersion model are of the order 4 x 10^{-3} mm/yr (1.6 x 10^{-5} in/yr).

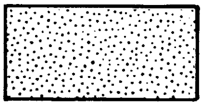
TABLE 4.1
BAYOU CHOCTAW SPR SITE
KEY TO GEOLOGIC SYMBOLS



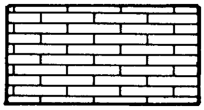
Salt



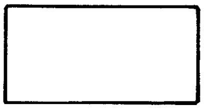
Caprock, predominantly gypsum-anhydrite, includes clay and sand



Sand and sandstone, may include thin clay or shale beds



Limestone (Heterostegina)

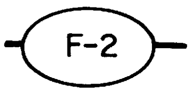


Undifferentiated clay and shale, includes sand where noted

Ⓐ

Geologic unit, see Section 6

Stratigraphic contact, dashed where inferred



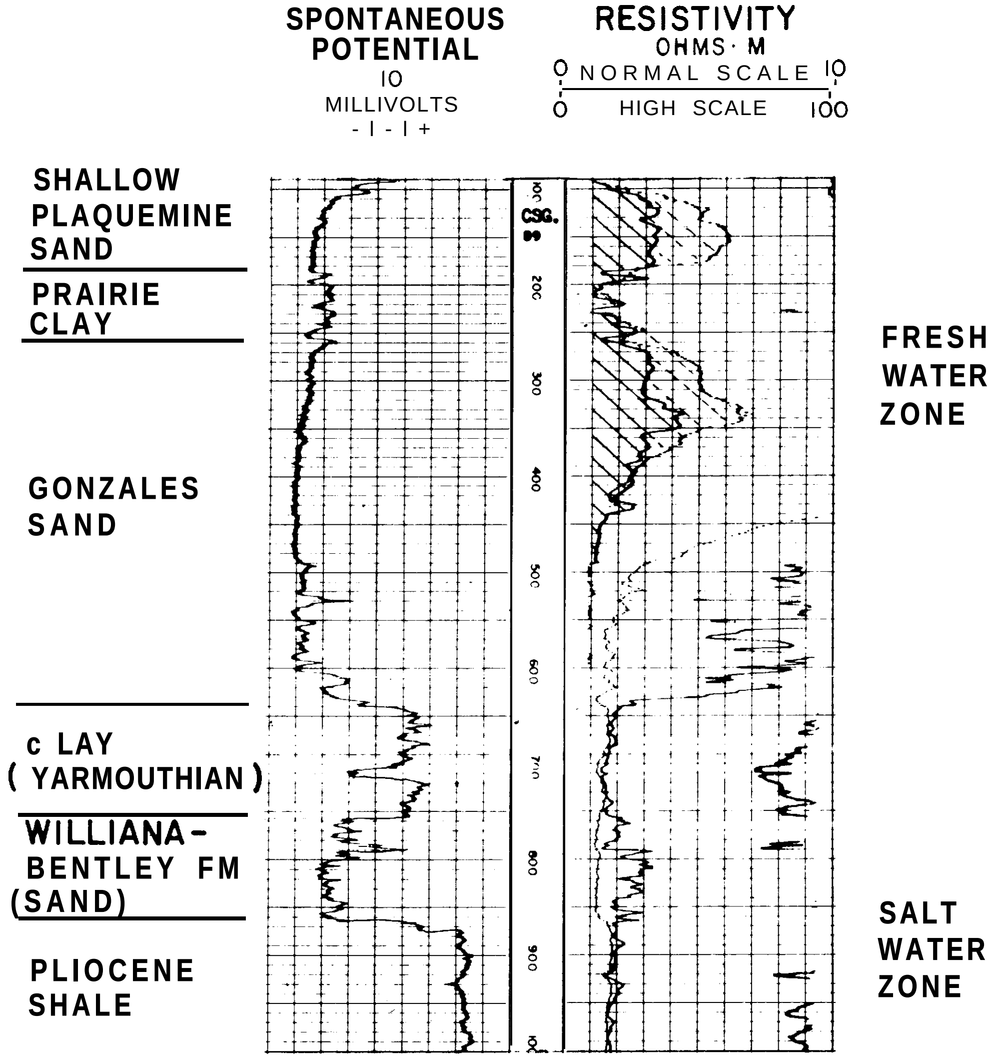
Normal fault, dashed where inferred. Number keyed to text. See Section 6

Well location showing logged interval (solid line) and well identification, Freeport wells unless otherwise noted.

CAVERN 18

Cavern profile. For details, see Section 8

FREEPORT OIL CO.
WILBERT MINERALS CORP.
WELL NO. 18 (F 18)



NOTE: DEPTH IN FEET MEASURED
FROM ROTARY TABLE.
(13.4 FT. ABOVE GROUND LEVEL)

BAYOU CHOCTAW SPR SITE
SAMPLE LOG OF NEAR-SURFACE SEDIMENTS

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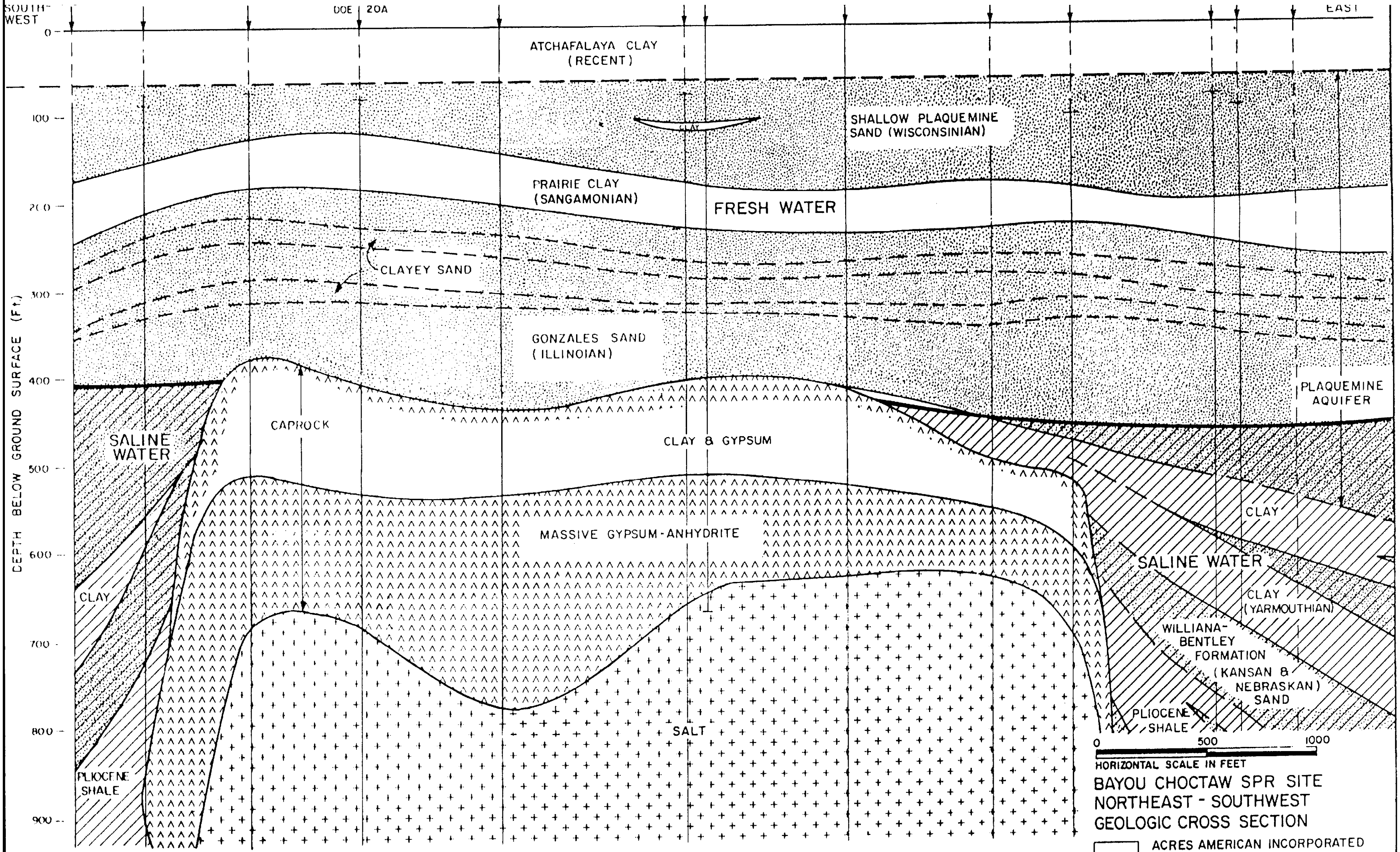
FIG. 4.1



BAYOU CHOCTAW SPR SITE
NORTHEAST - SOUTHWEST
GEOLOGIC CROSS SECTION

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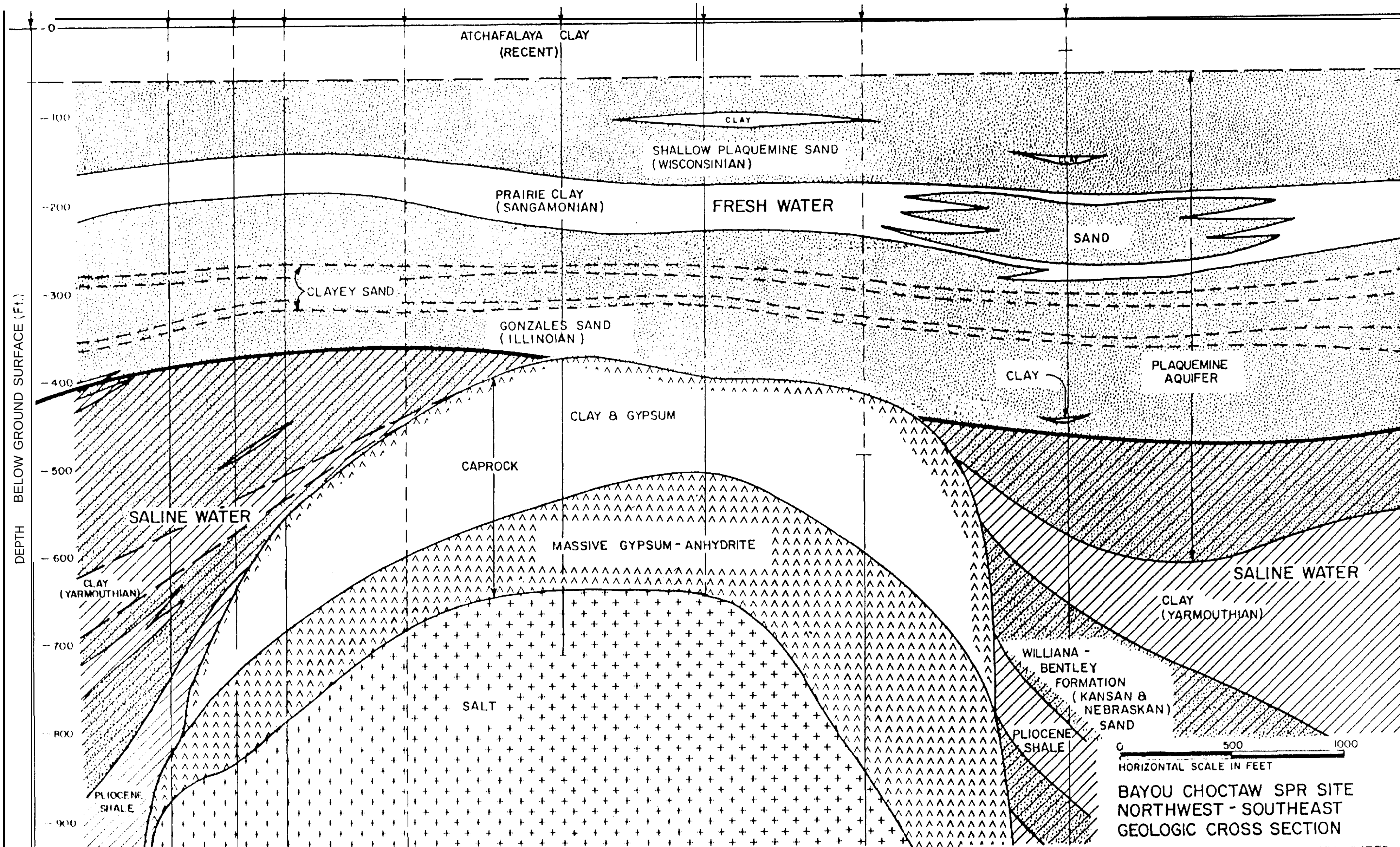
FIG. 4.2



BAYOU CHOCTAW SPR SITE
NORTHWEST - SOUTHEAST
GEOLOGIC CROSS SECTION

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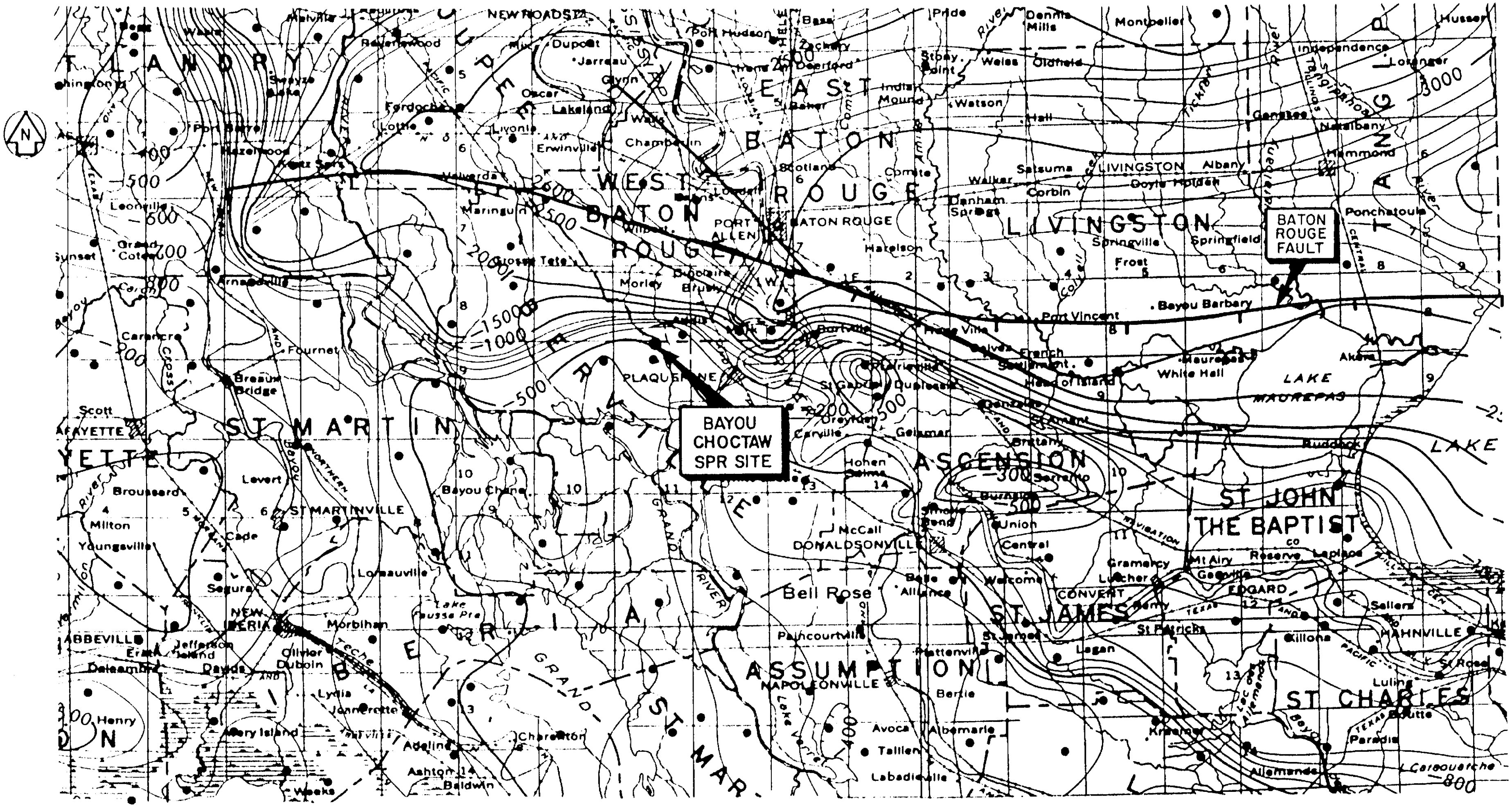
FIG. 4.3



LEGEND:

- CONTROL POINT
- —500— WATER-ZONE CONTOUR INTERVAL 100 AND 500 FEET BELOW MEAN SEA LEVEL

NOTE: 3000 mg/l DISSOLVED SOLIDS SURFACE DEFINES BASE OF THE SLIGHTLY-SALINE-WATER ZONE AND THE TOP OF THE MODERATELY-SALINE-WATER ZONE.

CONTOUR INTERVAL 100 & 500 FEET BELOW SEA LEVEL

10 5 0 10

SCALE IN MILES

ELEVATION OF 3000 mg/l DISSOLVED SOLIDS SURFACE

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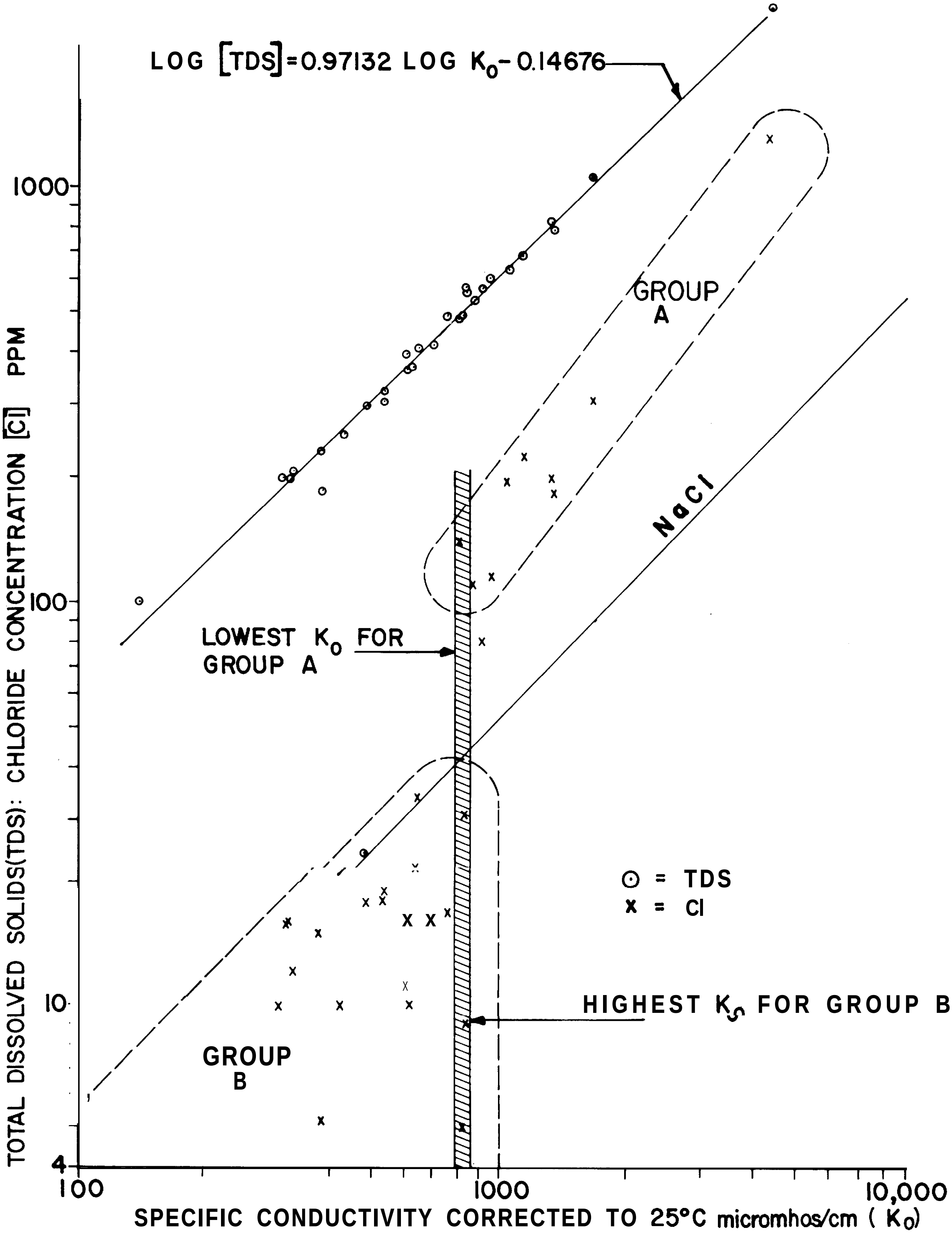
REFERENCE: WINSLOW, AND OTHERS, 1968



NOTE:
WATER SAMPLES FROM WELLS
IN IBERVILLE PARISH

REFERENCE : WHITEMAN, 1972

BAYOU CHOCTAW SPR SITE
RELATION OF DISSOLVED
SOLIDS CONDUCTIVITY

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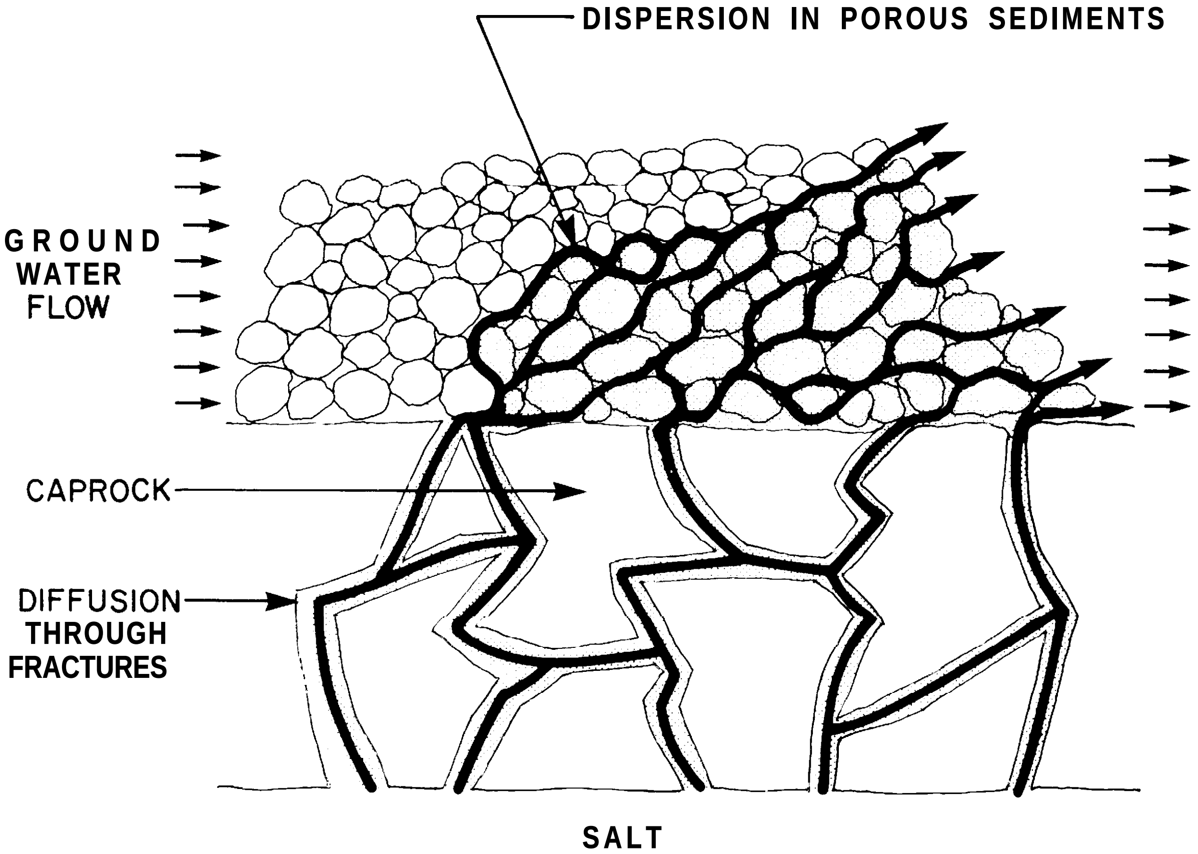
FIG. 4.5



BAYOU CHOCTAW SPR SITE MODEL FOR DISSOLUTION OF SALT BY DIFFUSION AND DISPERSION

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FIG. 4.6

5 - CAPROCK

5.1 - Introduction

The caprock at Bayou Choctaw was defined by data from sixty-one wells, which included electric, nuclear, and sonic well logs, and drillers logs. Additional information was obtained from samples from two core holes. Many of the deeper wells which penetrated the caprock were not logged in the caprock zone.

The caprock at Bayou Choctaw, as above all salt domes, is structurally complex and lithologically variable due to the nature of caprock fromation. The caprock forms as the salt dome rises and encounters saturated groundwater which dissolves both salt ($NaCl$) and anhydrite ($CaS04$). When the water becomes supersaturated with respect to anhydrite, it precipitates anhydrite over the top of the dome forming the caprock (Walker, 1974). During slower periods of dome growth, solutioning occurs faster than uplift resulting in cavities forming at the salt/ caprock contact. As the cavities enlarge, the overlying caprock collapses into the voids. This cycle is continually repeated, resulting in the formation of a very complex caprock sequence. Gypsum ($CaS04 \cdot 2H_2O$) forms in the caprock as anhydrite is hydrated by circulating groundwater.

Although few individual beds can be traced through the caprock at Bayou Choctaw, two distinct zones within the caprock can be distinguished on the well logs and mapped across the site. Figure 5.1 is a sample electric log which shows the distinct differences between the two caprock zones.

The upper zone is termed the clay and gypsum zone. This zone generally has low resistivity interspersed with thin peaks of high resistivity (Figure 5.1). The character of the log in the upper zone indicates clay with layers of evaporites, gypsum and/or anhydrite. Although it is not possible to distinguish gypsum from anhydrite in the electric or gamma logs, samples from Core Holes 1 and 2 (DOE CH 1 and DOE CH 2 on Figure 5.2) show that the layers are gypsum. The top of this zone has been picked on the shallowest, high resistivity peak (gypsum layer) overlying the dome. This zone appears to be, in part, equivalent to the pebble-clay unit identified by Hendron and Mahar (1978).

The lower zone is termed the massive gypsum-anhydrite zone. This zone has generally high resistivity with fewer layers of low resistivity. The logs indicate predominantly evaporite with some clay. Samples from this zone in Core Holes 1 and 2 are a mixture of gypsum and anhydrite. The contact between the two zones is picked at the sharp increase in resistivity from the clays of the clay and gypsum unit to the gypsum-anhydrite of the massive unit. The massive gypsum-anhydrite unit is equivalent to the gypsum-clay and massive units of Hendron and Mahar (1978). A list of caprock tops is included in the Appendix as Table A-3. Sections through the caprock can be found in Section 4, Figures 4.2 and 4.3, in Section 6, Figures 6.2 - 6.8, 6.26 and 6.27 and in the Appendix, Figure B-8.

5.2 - Caprock Lithology

The most detailed information on caprock lithology can be obtained from the core samples from Core Holes 1 and 2, since well logs can only give general lithologic information. The following lithologic descriptions are based principally on Acres interpretation of the core samples and well logs with additional information from reports by PB/KBB (1978e), Hendron and Mahar (1978) and Ferrel (1978).

5.2.1 - Clay and Gypsum Zone

The clay and gypsum zone is composed of layers of gypsum intercalated with clay. The proportion of clay to gypsum is highly variable, with generally more clay than gypsum. The clay is gray to black, silty to sandy, plastic, stiff, and occasionally fissured. Within the clay are rounded, pebble-size nodules of gypsum and, rarely, calcite with clusters of euhedral gypsum crystals. Some nodules show evidence of brecciation and rehealing. The gypsum layers are composed of partially altered and recrystallized gypsum. The recrystallized gypsum occurs as very thin, finely crystalline layers with the altered gypsum. In Core Holes 1 and 2, gypsum layers ranged from 0.5 to 2 feet thick. In some wells, for example F 45 (Figure 5.1), the initial gypsum layer can be from 20 to 30 feet thick. The clay-gypsum contacts are sharp, subhorizontal and show no evidence of movement, (Hendron and Mahar, 1978). In Core Hole 2, two layers of unconsolidated sand were recovered near the base of the zone. A two-foot void near the top of the zone was intersected in Core Hole 2.

The clay and gypsum zone is probably equivalent to the Pliocene and lower Pleistocene clays and shales surrounding the dome (Figures 4.2 and 4.3). As the dome rose through the sediments, anhydrite layers were initially deposited by circulating groundwater and later hydrated to gypsum. The presence of the gypsum nodules suggests that at times, the caprock was very near, or exposed at, the surface and was being eroded. Only trace amounts of calcite have been found in the caprock.

5.2.2 - Massive Gypsum-Anhydrite Zone

There is disagreement among those who have examined samples from the core holes as to the actual mineralogy of the caprock of this zone. Acres (this study), PB/KBB (1978) and Hendron and Mahar (1978) on extensive examination have described the core samples in the field as predominantly anhydrite with minor gypsum. Ferrel (1978), on the other hand, reports that based on x-ray and optical examination of a few samples, the rock is gypsum with minor anhydrite. The term gypsum-anhydrite is used in this discussion.

The lithologic description of this zone is based on core samples from Core Holes 1 and 2 and from well logs. This lower caprock zone is predominantly gypsum-anhydrite with minor amounts of clay, sand and gypsum. The gypsum-anhydrite is black with very thin, horizontal layers of white, finely crystalline gypsum. The black color is due to impurities such as silt and clay particles within the gypsum-anhydrite. The gypsum-anhydrite is occasionally vuggy. Layers of euhedral gypsum crystals, up to 2 inches, are sometimes found along the cleavage planes and form a weak surface along which the core breaks. Hendron and Mahar (1978) report that "the presence of gypsum crystals has little effect on the overall stability of the caprock because they tend to be isolated and are very small".

The top of this zone is distinguished by a relatively unfractured, massive layer of gypsum-anhydrite. This layer is variable in thickness but generally ranges from 20 to 60 feet thick. Well log data indicates that below the initial massive layer, the gypsum-anhydrite tends to become more fractured and layered. On the log of well F 45 (Figure 5.1), there are two massive layers from 655 to 685 feet and from 700 to 755 feet. These are indicated by zones of high resistivity, which are underlain by a zone of moderate resistivity with thin peaks of high resistivity. The lower resistivity is due primarily to water filled fractures in the gypsum-anhydrite and also to the presence of clay and, occasionally, sand layers. The higher resistivity zones are unfractured layers of gypsum-anhydrite similar to, but thinner than, the top layer.

Changes in lithology can occur rapidly within the lower zone. For example, in F 71, a 20-foot clay layer overlies the shale; whereas, in F 69, 500 feet to the west, the salt is overlain by 35 feet of evaporite.

In Core Hole 2, which overlies Cavern 4, core from below 593 feet consisted of altered, horizontally laminated, gypsum-anhydrite which is fractured parallel to the laminations. Cleavage planes are spaced from 0.25 to 1.0 inches apart. This fractured zone overlies a two-foot void which was encountered during drilling. No core recovery was made below the void, but it was assumed that the material drilled was salt. A possible 40-foot void at the salt/caprock contact was interpreted on the log of the hole for Cavern 8A.

The only evidence of faulting in the caprock was observed in Core Hole 1 at 598 feet where the gypsum-anhydrite layers dip to 40" and are offset approximately 5 mm by a set of small faults. Because Core Holes 1 and 2 were vertical, it was unlikely that they would intersect any steeply dipping faults which would be expected to occur in the caprock.

5.3 - Thickness and Structure

5.3.1 - Clay and Gypsum Zone

The clay and gypsum zone varies in thickness from 100 to 150 feet over the top of the dome and pinches out at depth (Figure 4.2 and 4.3). The unit extends around the edge of the dome to a depth of approximately 800 feet. The clay and gypsum zone lies within 400 to 450 feet of the surface over the top of the dome. This unit is generally continuous; however, it has not been identified in the northwest area of the dome in wells F 11, F 12 and F 55. In wells F 11 and F 12, a thick, massive evaporite layer is present at the stratigraphic level where the clay and gypsum zone is expected to occur. This evaporite has been defined as part of the massive gypsum-anhydrite zone.

5.3.2 - Massive Gypsum-Anhydrite Zone

A caprock isopach map of the massive gypsum-anhydrite zone is shown as Figure 5.2. The thickness of the caprock was calculated on the distance from a point on the top of the caprock along a line normal to the salt surface. The massive caprock zone generally ranges between 100 and 200 feet thick across the top of the dome and pinches out at depth. The zone is less than 100 feet thick in an east-west trending belt across the north-central part of the dome and thickens to the northwest and south, especially in the area of the salt overhang on the west flank. On the southwest flank, a ridge of massive gypsum-anhydrite over 200 feet thick parallels the edge of the dome. To the northwest, the unit is over 350 feet thick.

In wells F 11 and F 12 drilled in this northwest section, the massive gypsum-anhydrite is underlain by thick shales and sands, atypical of the lower part of this zone. Salt contours in this area show an embayment into the salt (Figure 6.19). This area lies on the downdip side of the northeast-southwest trending active fault which runs through the north flank of the dome (see Section 6). Therefore, this anomalously thick caprock zone may be the result of a block of salt slipping off the side of the dome along the fault while the caprock remained in place. The void formed between the caprock and salt may have been infilled from the surrounding sediments resulting in the apparent over-thickening of the zone.

A caprock structure contour map is shown as Figure 5.3. The map is constructed on the top of the massive gypsum-anhydrite zone. The shape of the massive zone is nearly that of the salt dome (Figure 6.19), that is, slightly triangular in plan. The surface appears nearly horizontal (although in reality, probably quite irregular) and lies within 500 to 600 feet of the surface. The top of the massive zone should not be considered as a stratigraphically continuous, correlatable layer across the dome. Segments of the massive caprock formed at various times depending on the areas of salt movement and dissolution. Below 600 feet, the surface begins to dip away from the dome. The dip of the massive caprock is nearly vertical where the unit pinches out on the dome flanks.

The extent of the massive caprock along the flanks of the dome are based on scattered wells and approximated projection. Twenty-three wells which penetrate salt do not show evidence of caprock (Table A-3). The best well control on the extent of the massive caprock is between wells F 12, which enters caprock at 635 feet, and well F 5, 120 feet to the west, which was drilled to 2,960 feet and did not penetrate caprock or salt.

Based on these wells, the massive gypsum-anhydrite contact was projected along a series of cross-sections around the dome. The caprock extends to between 1,000 and 1,500 feet, except on the southeast flank where it extends nearly to 2,000 feet (Figure 5.3). Due to the lack of well control, 100-foot contours are shown only to 1,000 feet. A 1,500 foot contour is shown on the southeast flank based on wells F 16 and C 25. The zero isopach line marks the extent of the caprock on the eastern flank of the dome. However, on the west flank, the caprock dips steeply below 600 feet and is overhung generally below 900 to 1,000 feet. Because of the overhang, the edge of the caprock does not coincide with the zero isopach which is below the overhang. The edge of caprock is drawn on the projection of the farthest westward extent of the caprock based on wells C 9, F 5, F 12 and F 17.

The combined thickness of the two caprock units is generally between 200 and 300 feet over the top of the dome. This is thinner than most Gulf Coast domes whose estimated average caprock thickness is from 300 to 400 feet (Halbouty, 1979).

5.4 - Caprock Geochemistry

This section discusses the chemistry of the caprock and its affects on casing and cement. Groundwater within the caprock can be severely corrosive depending upon the caprock chemistry. An understanding of the caprock chemistry can be used to take preventative measures against the effects of casing corrosion and cement deterioration.

Chemical analyses were performed on caprock samples from Core Holes 1 and 2 by Ferrel (1978) for PB/KBB, Inc. His analyses indicate the caprock is composed predominantly of calcium sulfate (gypsum and anhydrite). Minor amounts of calcium carbonate (limestone) have been identified in sidewall cores from wells on the northwest flank of the dome.

No chemical analyses of the interstitial water within the Bayou Choctaw caprock have been done; however, caprock waters tend to be of moderate salinity with abundant calcium, sulfate and bicarbonate ions (Walker, 1974). Salinity increases with depth, being saturated in sodium and chloride in the connected voids along the salt/caprock contact.

The caprock lithology is indicative of its geochemical state. In most salt domes, unlike Bayou Choctaw, carbonate predominates over the sulfate. This is a result of the biogenic reaction between the sulfate and methane gas (commonly abundant around most domes):

$CaSO_4$	+ CH_4 $\longrightarrow$	$CaCO_3$	+ H_2S	+ H_2O
Anhydrite	Methane	Limestone	Hydrogen Sulfide	Water

Methane gas is abundant in the sediment and groundwater at Bayou Choctaw. However, because of the location of the caprock in the Plaquemine Aquifer (see Section 4), this gas is constantly being carried away from the caprock so that only small amounts of methane are available to react with anhydrite or gypsum. The predominance of sulfate indicates that the caprock is in a basic reducing environment (Walker, 1974).

The hydrogen sulfide produced in the reaction can cause casing corrosion in forms such as hydrogen blistering, embrittlement and stress cracking. Because at Bayou Choctaw the reaction goes only partially to completion, there is less hydrogen sulfide present in the caprock and so it is considered a less serious problem than at other domes.

Sulfate attack on cement has been a problem in the older wells. Caverns 1 and 10 were all completed before sulfate-resistant cement was available. Several cavern pressure failures can be attributed to cement breakdown. Sulfate resistant cement has been used for Caverns 11 through 20.

5.5 - Engineering and Physical Properties

By the nature of its formation, the caprock is a complicated geologic unit to define for engineering properties. Individual layers can be tested for strength and permeability, but it is the caprock as a whole which must be considered in an engineering evaluation. The caprock is lithologically heterogeneous containing interbedded layers of both higher strength, gypsum-anhydrite, and lower strength materials, clay and sand. The thick gypsum-anhydrite layer within the massive unit is the most competent layer within the caprock. It is likely that this layer is discontinuous, being broken by faults. Gypsum layers above and gypsum-anhydrite layers below the massive layer break along thin horizontal laminae of gypsum crystals and clay layers. Although these laminae and clay layers are discontinuous, there are enough layers to "combine and allow progressive failure of the caprock" (Hendron and Mahar, 1978).

Voids formed by salt solutioning at the salt/caprock contact caused collapse of the overlying caprock layers. The faulting and fracturing resulting from this collapse create openings for groundwater movement and a highly permeable zone.

Samples of caprock from Core Holes 1 and 2 were tested by Dames and Moore (1978) for PB/KBB to determine physical properties. The samples tested were from the massive gypsum-anhydrite unit at depths of 602 feet and 645 to 648 feet in Core Hole 1 and 558 to 642 feet in Core Hole 2. The test results are listed in Tables 5.1, 5.2 and 5.3.

Caprock moisture and bulk density are listed in Table 5.1. The moisture content of the samples varies from 6.3 percent to 19.3 percent. Dames & Moore (1978) reported that the moisture content may be partially the result of dehydration of the gypsum which occurred during oven drying. Bulk density data is less variable and averages 144.4 and 144.8 pounds per cubic foot (pcf) in Core Holes 1 and 2 respectively. The results of ultrasonic pulse velocities is shown in Table 5.2. Velocities were measured for both P and S waves. These velocities increased with increases in applied stress, both uniaxial and hydrostatic (Dames & Moore, 1978).

Uniaxial compressive strength tests were performed on samples from both core holes (Table 5.3). Samples from Core Hole 2 were somewhat stronger than those from Core Hole 1. Triaxial compression tests were performed on samples from Core Hole 2 (Table 5.3). These samples remained intact after failure although single and conjugate shear planes were visible in most cases. Elastic properties (Young's modulus and Poisson's ratio) were determined for the caprock samples (Table 5.3). In uniaxial compression, Young's modulus is about the same for all samples and averages 3.1 x 10^6 psi for Core Hole 1 and 2.28 x 10^6 for Core Hole 2. Poisson's ratio is somewhat higher in samples from Core Hole 1 (average 0.381) than Core Hole 2 (0.288) but the results are inconclusive. The lower values of Young's modulus for triaxial compression are the result of different computational methods. No values for Poisson's ratio were calculated because no lateral deformations were recorded during the triaxial testing (Dames & Moore, 1978).

TABLE 5.1

BAYOU CHOCTAW SPR SITE
CAPROCK MOISTURE AND BULK DENSITY

Boring Number	Depth* (ft)	As Received Density (pcf)	As Received Moisture (%)
DOE CH1	602.5	144.1	
	602.95		12.;
	645.6		13.5
	645.75	144.;	
	640.0		17.0
	648.05	145.8	
	648.4	143.5	
	648.75		11.7
DOE CH1	Mean Value	144.4	13.6
	Std. Dev.	1.0	2.4
DOE CH2	558.0	144.1	
	550.4		6.6
	566.0	142.9	19.6
	566.15	144.0	
	582. 1	145.9	19.7
	606.1	143.8	13.9
	634.3	145.6	11.1
	634.7	145.3	
	635.13	145.7	
	635.63	145.5	
	641.58	145.0	
	642.17		6.3
	642.25	145.4	
DOE CH2	Mean Value	144.8	12.9
	Std. Dev.	1.0	6.0

* Depth below rotating Kelly bushing which was 15 feet above ground surface.

Modified from Dames & Moore, 1978

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TABLE 5.2

BAYOU CHOCTAW SPR SITE
CAPROCK ULTRASONIC VELOCITIES

Boring Number	Depth*** (ft)	S. Wave Velocity (fps) =	=	=1000	=2	0	P Wave Velocity (fps) =	=	=	=	= 00
DOE CH1	602.5	10,007	10,152	10,202	10,430	-	16,975	17,184	17,326	17,470	-
	645.75	7,624	9,308	9,645	9,883	10,007	17,032	18,616	19,525	19,525	19,525
	648.05	7,980	8,704	8,818	8,911		17,053	17,870	18,874	19,198	
	648.4	7,305	7,501	7,569	7,569		16,849	17,464	17,464	17,647	
DOE CH1	Mean Value	8,229	8,916	9,059	9,198	10,007	16,977	17,784	18,297	18,460	19,525
	Std. Dev.	1,213	1,115	1,144	1,255		92	622	1,077	1,052	
DOE CH2	558.0						3,425	5,538	8,209		
	566.0						2,854	5,187	6,582		
	566.15						3,438	5,384	11,441		
	582.1						15,407	16,763	16,946		
	606.11						6,050	9,797	16,444		
	634.7						16,704	17,009	17,009		
	635.13						17,143	17,537	17,671		
	635.63						16,215	16,392	16,569		
DOE CH2	Mean Value						10,155	11,701	13,859		
	Std. Dev.						6,725	5,779	4,452		

Boring Number	Depth*** (ft)	**= 0	= 500	= 1000	= 2500
DOE CH2	634.33	16,585	16,736	16,966	17,045
	641.58	16,851	17,147	17,301	17,376
	642.25		16,589		
DOE CH2	Mean Value	16,718	16,824	17,134	17,211
	Std. Dev.	188	289	237	234

* = axial stress in psi
** = hydrostatic stress in psi
*** Depth below rotating Kelly bushing which was 15 ft above ground surface.

Modified from Dames & Moore, 1978.

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TABLE 5.3

BAYOU CHOCTAW SPR SITE
CAPROCK STRENGTH AND ELASTIC PROPERTY DATA SUMMARY

Boring Number	Depth* (ft)	Confining Pressure (psi)	Failure Stress[1] (psi)	Young's Modulus' $(psi \times 10^6)$	Poisson's Ratio	Approx. Failure Strain (%)
DOE CH1	602.5	0	2082	4.5	0.472	1
	648.052	0	2044	3.3	0.670	1
	648.4	0	2796	3.1	0.289	1
DOE CH1	Mean Value[3]	-	2307	3.1	0.381	-
	Std. Dev.	-	424	1.4	0.129	-
DOE CH2	558.0	0	2740	0.84	0.220	1
	582.1	0	3386	4.25	0.319	1
	606.11	0	3625	3.49	0.229	1
	634.33	0	3524	3.65	0.327	1
	634.71	500	4052[4]	1.153		.5
	635.13	1000	5238[4]	1.213		.6
	635.63	2500	6763[4]	0.80[3]		.a
	641.58	0	2927	4.05	0.345	1
	642.25	500	41054	1.07		.4
DOE CH2	Mean Value	-	3240[5]	2.28	0.288	-
	Std. Dev.	-	387[5]	1.52	0.059	-

Notes:

1) Not corrected for area change due to specimen deformation, but corrected for length to diameter ratio of 2.0 unless otherwise noted.

2) Failure influenced by pre-existing weakness plane in specimen.

3) Does not include data for 648.05 ft.

4) Corrected for cross-sectional area change due to specimen deformation.

5) Uniaxial strength data only.

* Depth below rotating Kelly bushing which was 15 ft above ground surface.

Modified from Dames & Moore, 1978.

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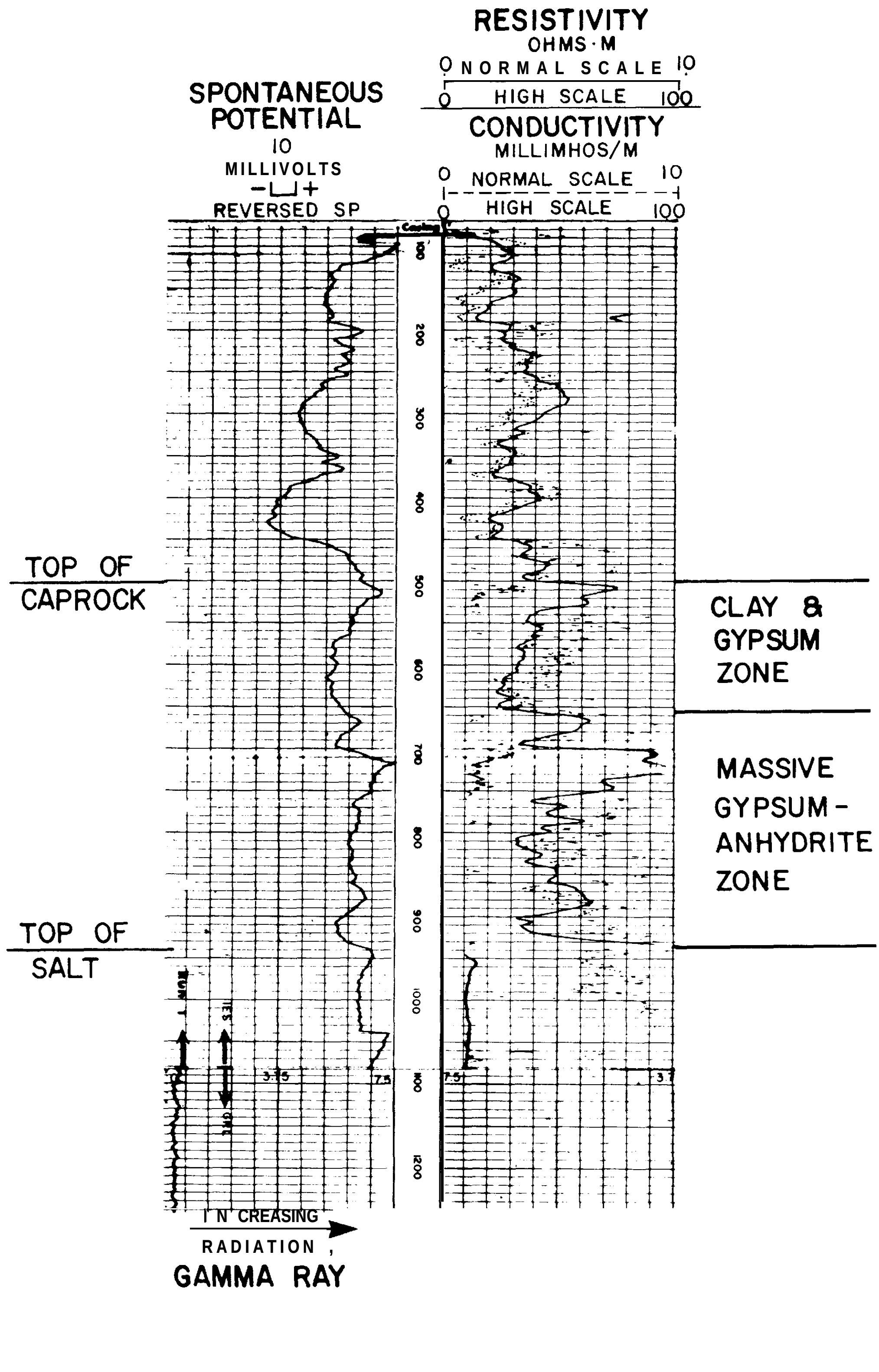
FREEPORT OIL CO.
WILBERT MINERALS CORP.
WELL NO. 45 (F45)

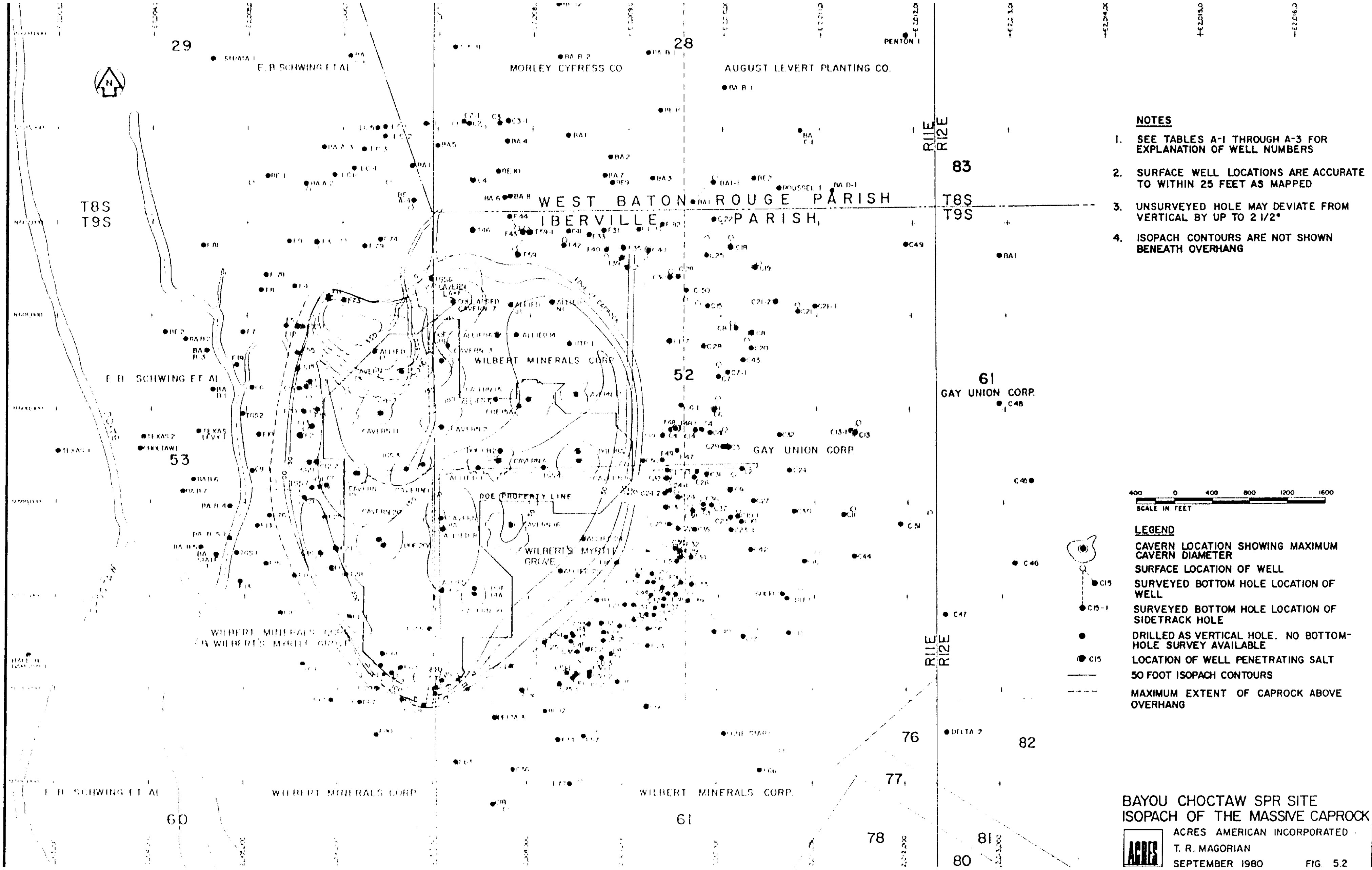


NOTE : DEPTH IN FEET MEASURED FROM 1 FT. ABOVE ROTARY TABLE. (APPROXIMATELY 15FT. ABOVE GROUND LEVEL)

BAYOU CHOCTAW SPR SITE
SAMPLE CAPROCK LOG

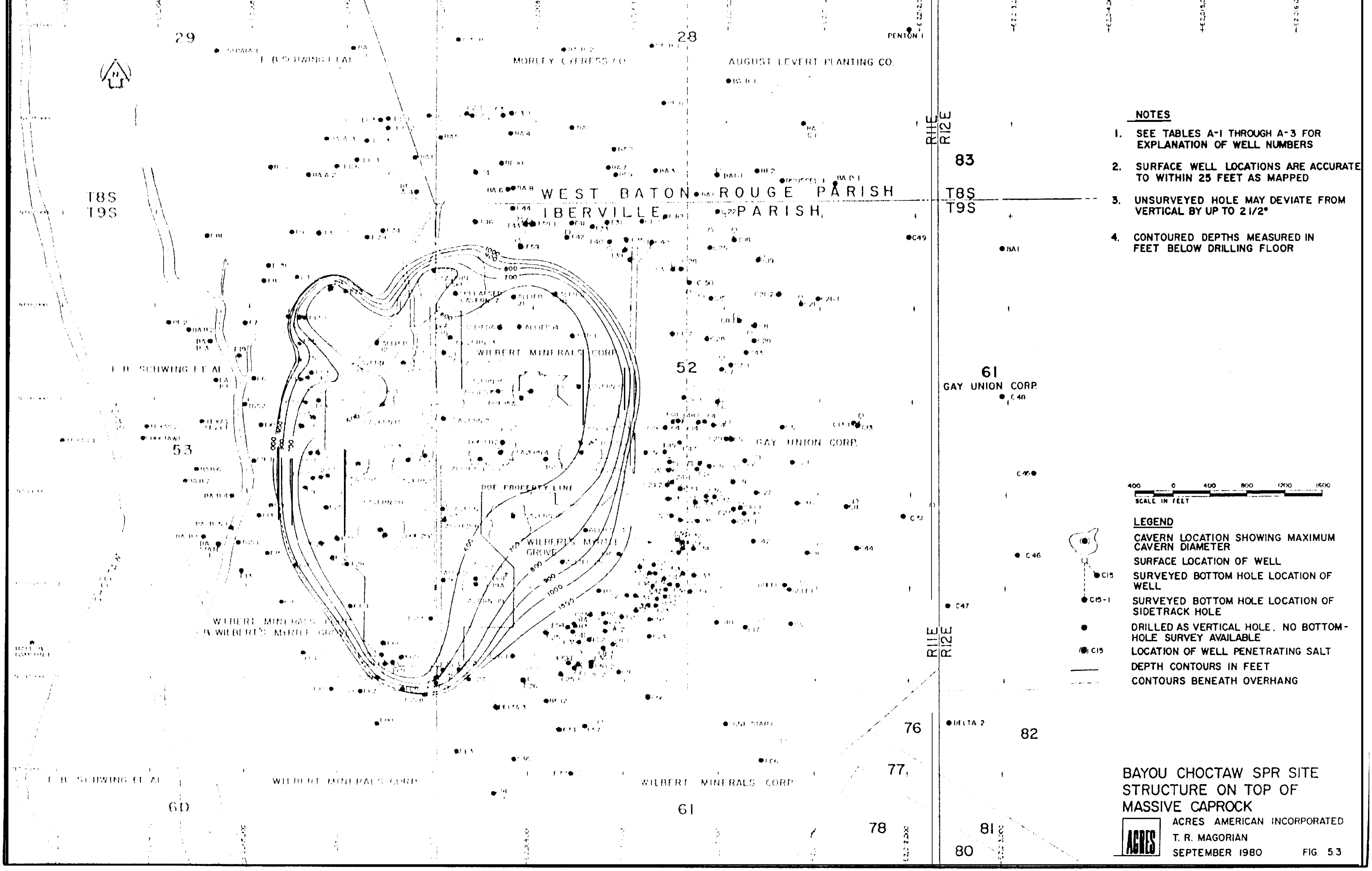
ACRES AMERICAN INCORPORATED
T.R. MAGORIAN
SEPTEMBER 19 80

FIG. 5.1



BAYOU CHOCTAW SPR SITE
ISOPACH OF THE MASSIVE CAPROCK

FIG. 5.2



BAYOU CHOCTAW SPR SITE
STRUCTURE ON TOP OF
MASSIVE CAPROCK

ACRES AMERICAN INCORPORATED
T. R. MAGORIAN
SEPTEMBER 1980

FIG. 5.3

6 - SALT DOME

6.1 - Introduction

Utilizing the available well log data, this study has used practical methods of sediment convergence and salt edge tectonics to define the geometry of the salt dome. The methods are based on the assumption that the shape of the dome can be determined from the properties of the surrounding sediments and their deformational characteristics. It is well established that the dip of shales and thin sand units adjacent to a dome tend to be asymptotic (vertical) to the salt at the edge of the dome. Therefore, by projecting the increasing dip of two or more beds towards the salt, a point where the beds converge can be plotted on a geologic section. This geometric relationship allows more accurate prediction of the salt edge. Similarly, detailed evaluation of the fault geometry in the adjacent sediments also assists in defining the salt dome boundaries.

Using well log data, a series of sections have been constructed on and around the dome to detail the subsurface structures to a depth of nearly 8,000 feet. Lists of the depths to the tops of the geologic units used in constructing the sections are in the Appendix as Tables A-1, A-2 and A-3. For the most part, accuracy of the majority of the dome geometry as shown in the sections is considered to be within plus or minus 100 feet. The base map showing section lines is presented on Figure 6.1. Sections were drawn radially (A-A' through L-L') and tangentially (M-M' through T-T') to the dome and are shown on Figures 6.2 - 6.8, 6.20, 6.26 and 6.27, and Figures B-1 through B-8 in Appendix B, respectively.

Based on the sections, structure maps of the top of the salt and key marker units were drawn to further define the geometry of the dome and the extent of faulting. These maps are shows on Figures 6.12 through 6.19.

A detailed list of the Pliocene, Miocene and Oligocene geologic units surrounding Bayou Choctaw is presented as Tables 6.1 and 6.2. The information on these tables is based on electric log data from wells within three miles of the dome and includes the map symbols used on the sections, description of the sediment types and the depositional environment.

6.2 - Structure & Stratigraphy Around the Dome

6.2.1 - Introduction

The sediments flanking the dome are steeply dipping sands, shales and limestones of Pliocene, Miocene, and Oligocene age. The deepest wells drilled around the dome were completed in the Frio Formation (Oligocene) or salt so that sediments older than the Oligocene have not been penetrated. The detailed stratigraphy around the dome is discussed in this section.

Many of the sands close to the dome have been found to be gas and oil productive. Most of these reservoirs are segmented by faulting. Mappable fault displacement stops at the dome where is becomes indistinguishable due to the plastic and self-healing nature of the salt mass. Faulting is discussed in detail in Section 6.4.

6.2.2 - Pliocene

The Pliocene sedimentary rocks at Bayou Choctaw consist of shale with minor sands which were deposited in a series of backswamp and alluvial levee deposits (Table 6.1). The caprock is probably composed of considerable Pliocene material. The relatively simple and undeformed structure of the Pliocene can be seen in Sections A-A' through G-G' (Figures 6.2 through 6.8). Faulting occurs mostly below the Pliocene in the Miocene units.

The effect of domal uplift on the Pliocene sediments is evident on Figure 6.9. Surrounding the dome, the top of the Pliocene is at a depth of approximately 1,000 feet, while at the edge of the dome the Pliocene top is less than 700 feet deep and is probably close to 600 feet within equivalent units in the caprock.

The isopach of the Pliocene and the upper Miocene shale (Figure 6.10) shows the effect of the dome on sedimentation. The shale thins from more than 1,400 feet away from the dome to less than 1,000 feet at the dome edge.

6.2.3 - Miocene

The Miocene consists of over a mile-thick pile of deltaic sands with many individual sand units on the order of hundreds of feet thick. Prentice (1978) has numbered the Miocene sand intervals between 4,000 and 7,000 feet deep, which are more attractive for brine disposal. The series numbers have been extended to the bottom of the deltaic sand pile. Miocene sands are found to a depth of 9,500 feet in the present disposal area south of the site and to a depth ranging between 1,000 and 8,000 feet near the salt. Below the No. 16 Sand in the site area, the sands become thinner, muddier and separated by thicker marine shales.

Table 6.1 provides a breakdown of the Miocene stratigraphy in and around the Bayou Choctaw dome. The Miocene sands represent a typical delta regression that can be divided into a sequence of distinct sand types based on mode of deposition. Each of these sand types has a typical orientation and extension so that, by knowing its type, a particular sand can be mapped or predicted in lateral extent with a great degree of accuracy. In addition, at particular places in the deltaic sequence, the sand types can be identified or confirmed by permeability variations which are readily detectable on the electric logs.

The two main contrasting sand types are beach sands and channel sands. The base of the delta (No. 18 sand) overlies marine shales. This is a thin widely-spread sheet of sand extending into the shale. Above several of these deltaic sands are offshore bar or beach type sands. Figure 6.11 is a sample log of a typical Miocene sequence and shows the interpretation of the sediment types.

These shoreline sands are overlain by backbay muds, which are often highly organic. These lagoonal muds are succeeded by river channel sands which are relatively thin. They are gravelly at the base, finer upward and highly permeable due to the high-velocity sorting and cross-bedding of the fluvial currents. Most of these channel sands were deposited on the inside of meandering river bends as point bars. Therefore, these sands are generally limited in extent and are formed into crescent shape deposits.

The permeabilities of the beach sands tend to average half a darcy as contrasted to channel sands which have permeabilities as high as six darcies at their base and average two to three darcies (Figure 6.11). The marine beach and offshore bar sands lack the basal gravel found in channel or point bar sands and so are less permeable. Additional details of Miocene sediments are included in brine disposal studies performed by Magorian (1978). These include porosity and permeability data, extent and continuity of sands and structure in the area south of the dome.

Structure contour maps on the tops of the "A" and Numbers 2, 4, 8 and 16 Sands are presented as Figures 6.12 through 6.16. These maps are essentially slices through the dome and were drawn to define the salt edge at the level of the particular unit being mapped. The maps show the increase in area of the dome with depth. This is particularly evident in comparing the maps of the "A" and No. 16 Sands (Figures 6.12 and 6.16). The amount of displacement on the top of the units also increases with depth showing the affect of dome uplift on the surrounding sediments. The "A" Sand is at a depth of approximately 3,600 feet away from the dome and as shallow as 2,500 feet at the dome edge for a maximum displacement of 1,100 feet. The No. 16 Sand is at a depth of about 8,200 feet away from the dome and up to 5,500 feet against the dome edge for a maximum displacement of 2,700 feet. Sand No. 1 is the "2,800 foot" freshwater aquifer at Baton Rouge (Smith, 1976). No marine shale is present between it and the No. 2 Sand as evidence in logs from Freeport Wells 6, 9, and 11 (see Figure 2.1). However, the No. 1 Sand is saline in the brine disposal area south of the dome.

Thick marine shales are found around the dome at 5,000 feet between the No. 2 and No. 3 Sands; at 6,000 feet between No. 4 and 5 Sands; and at 7,000 feet between the No. 6 and 7 Sands (Figures 6.2 through 6.8).

Continuity of the sand units in the immediate area of the site are excellent with the exception of No. 6, a localized beach sand, which is found in only some of the surrounding wells. The sequence of Sand No. 5 and 6 is overlain by the most extensive marine transgression of the Miocene, the Amphistegina B shale, followed by a regular sequence of sediments starting with the No. 4 Sand.

6.2.4 - Oligocene

The Oligocene sediments are the oldest penetrated by well drilling at the Bayou Choctaw site (Figures 6.2 through 6.7). These sediments are deep-water clays and silts and pelagic (organic) shales interspersed with turbidite sands. These sands were deposited by currents flowing down the steep slopes at the edge of the continental shelf into deep-water areas. The Oligocene at the site is represented by the Vicksburg, Frio and Anahuac formations, the Marginulina howei sand and the Heterostegina reef limestone. A description of these units is presented in Table 6.2. Structure on the top of the Oligocene (Heterostegina) and the Frio are shown on Figures 6.17 and 6.18.

6.3 - Salt Dome Geometry

6.3.1 - Salt Dome Emplacement

Salt responds plastically under high temperature and pressure conditions. The specific gravity of salt is 2.2. Thus when the surrounding material around the salt equals and/or exceeds this density, the salt becomes "buoyant" and starts an upward migration through the overlying material. In this part of the Gulf Coast, salt buoyancy begins at between 8,000 to 12,000 feet (as shown by density logs in the disposal area) and discussed in Section 6.5. The additional pressure required to initiate salt movement at this depth and temperature is quite small (Ode', 1968). Gussow (1968) and others, however, have pointed out that intrusive salt features require burial to about 12,000 feet depth in order to break through the crestal sediments on the tops of folds or salt ridges from which the domes form.

The mode of salt dome emplacement is well described by Kupfer (1974). and others. Therefore, it is not considered necessary in this report to detail these previous works. It is important to note, however, that the salt migrates upward in a series of salt "spines" which tend to override themselves in their upward migration. The overlying beds which are pierced by the intruding salt are dragged upward along the salt body resulting in them being pinched out, smeared along the salt edge, incorporated into the salt and faulted (Figures 6.2 through 6.8). When the salt reaches a depth where it is heavier than the surrounding sediments, overhangs develop causing the salt to "slump" back or break off into the lighter surrounding sediments.

6.3.2 - Dome Geometry

The geometry of the Bayou Choctaw dome as determined from available well data is defined by depth contours on the salt surface (Figure 6.19) and by Sections A-A' through H-H' (Figures 6.2 through 6.8 and 6.20).

The top of the dome lies between 600 and 700 feet below the surface. The salt surface over the top of the dome is relatively flat, sloping gently outward to a depth of approximately 1,000 feet where the angle steepens sharply. The cross-sectional area within the 1,000 foot contour is about 284 acres. A moderate depression across the top of the dome, near the south flank, is possibly caused by solutioning.

The east flank dips gently downward to 1,500 feet where the dip increases to approximately 80° between 2,000 and 6,000 feet. The west flank of the dome is overhung between 1,000 and 5,000 feet. Below 6,000 to 8,000 feet on both flanks, the slope of the salt surface begins to flatten toward 60°.

The change in the dip of the salt mass is demonstrated by the sectional area of the dome at 5,000 feet which is 371 acres. By 9,000 feet, however, the area has increased to 742 acres. The steepest dip is found on the west flank where there is the pronounced caprock and salt overhang. Other small overhangs are indicated on the east and north flanks (see Section 6.3.4).

Boundaries of the deep salt were based on the key pelagic markers: Anahuac Shale, the upper Frio Formation, and the individual biostratigraphic zones within the Frio (Miogypsinoides, Cibicides hazzardi, Marginulina texana, Bolivina mexicana and Nodosaria blanpiedi) (Table 6.2). These units are sensitive to uplift and tend to pinch out near the edge of the salt. An isopach of the Anahuac shale (Figure 6.21) shows the thinning of the shale as it nears the dome boundary. A deep pelagic zone map showing the areas of pelagic sediments around the dome is shown on Figure 6.22. The area where the deep pelagic zones are absent reflects even deeper salt uplift. The bulge to the northwest may reflect extension of the base of the dome along the underlying salt ridge. The area absent of these sediments is interpreted as marking the approximate boundary of the salt between 12,000 and 15,000 feet.

6.3.3 - Rate of Domal Uplift

The coastal salt domes have risen through over five miles of accumulating sediment along distinct salt ridges and regional growth faults (see Section 3). Upward motion of the salt has been steady, at least since the Miocene when deltaic sedimentation reached the area. The rate of uplift has been calculated using both the displacement on top of the Pliocene (Figure 6.9) as well as by defining the average stratigraphic dip since deposition of the Miocene No. 2 Sand. The Pliocene displacement shows an average growth rate of 2.8×10^{-4} in/yr, while the dips on the Miocene show growths on the order of 3.5×10^{-4} in/yr (Figure B-1).

6.3.4 - Salt Dome Structure

As previously stated, the current interpretation of the dome geology and geometry has been based on over 300 wells drilled on and around the dome. Bayou Choctaw shows a consistent history of central domal uplift without the formation of any large rim synclines or other evidence of salt exhaustion or stagnation. This section gives a general discussion of several key features of dome geometry and how they may affect SPR facilities.

a. Salt Inclusions

A number of thin salt sections have been logged along the western, northern, and east-central edges of the dome where the salt overhangs into the soft sediments. These sections are either "inclusions" of sediment into salt mass or pieces of detached salt that have separated from the main salt body. Salt outliers or inclusions in the sediment are eventually dissolved away; whereas, sediment inclusions inside the main salt mass are better preserved.

As discussed in Section 6.3.1, salt overhangs develop at shallow depth where the salt becomes heavier than the unconsolidated sediments and lenses, or blocks of salt detached themselves gravitationally from the underside of the main salt body. The reduction of confining pressure may also allow the salt to mushroom slightly by recrystallization. The voids between these detached blocks are infilled with muds and sands and became subject to continued domal uplift (Kupfer,1974). Figure 6.23 is a map of zones where salt "inclusions" have separated from the dome and dropped into the surrounding sediments. These overhangs indicate generally unstable areas around the periphery of the dome. All observed inclusions appear to be associated with overhangs. This disturbed zone around the periphery of the dome often reaches 300 feet in thickness as shown on sections B-B' and H-H' (Figures 6.3 and 6.20).

Figure 6.24 is a plot of salt inclusion thickness as measured vertically along the drill holes with respect to depth below the surface. The plot suggests that the "thickness" of the inclusions increases with depth. This relationship is probably attributed to increased solutioning around the dome perimeter at the shallower depths resulting in the removal of much of the inclusions.

b. West Flank Overhang

As shown on Sections A-A' through G-G' (Figures 6.2 through 6.8), the west flank of the Bayou Choctaw overhangs into the surrounding sediments. The work performed for this study enhances the earlier interpretation made by Oden (1978) which shows the average strike of the overhang being approximately N10°W and dipping 80°E (holes intersecting the base of the solid salt between 78° and 84°).

c. South Corner

At the south edge of the dome, the west side overhang swings around in a complex series of salt spines. Although smooth contours have been shown on Figure 6.19 delineating this overhang, further studies will be required along the east flank to accurately delineate the salt configuration. However, based on existing data, the salt boundary must swing towards the east near Precise Exploration Company Well No. 4 (Figure 6.19). The south edge of the overhang must extend near to or just east of Freeport Wells No. 71 and No. 72 (Section E-E', Figure 6.6).

d. Northeast Corner

An overhang exists along the north side of the dome. This overhang is much smaller and shallower than that along the west side. It is associated with movement along Fault F-1 discussed in Section 6.4 below. The sharp northeast corner (Section C-C', Figure 6.4) is at the intersection of faults F-1 and F-3 as shown on tangential Section N-N' (Figure B-2). No salt caverns are located in close proximity to the east flank.

e. "Bowtie" Structure

Section H-H' (Figure 6.20) along the eastern edge of the dome shows a deep overhang with a "bowtie" type structure forming a complex obtuse corner of the dome. This overhang is formed where Fault F-2 (see Section 6.4.3) has cut the salt resulting in sliding of the salt downward onto the Heterostegina reef. The overhang area is very small and has been penetrated by Carter-Gay Union wells 31 and 36. The small zone of salt inclusions on the east flank (Figure 6.23) represent this area. Multiple sand convergence is particularly well documented immediately over the "bowtie" north above the main salt mass and active fault F-2.

6.4 - Dome-Related Faulting

6.4.1 - Introduction

The Bayou Choctaw salt dome is a piercement structure which has penetrated Mesozoic through Quaternary sediments. As in other types of intrusions, the salt dome must displace the overlying sediments as it is emplaced. As uplift proceeds, any sediment deposited over the top of the dome must be either pushed aside or eroded away. On domes with surface expression such as Big Hill, sediments are eroded off the top of the dome as it rises. At Bayou Choctaw, the sedimentary record indicates that the dome has had no surface expression which means normal sedimentation has occurred over the dome as it was rising. As each layer of sediment was deposited over the dome, the upward movement of the salt stretched it to the point of failure, essentially pulling the layer apart in a series of normal faults. The mechanical failure of the sediments surrounding the dome has caused the faults to develop radially from, and tangentially to, the dome in a series of graben-horst structures.

Dips on fault planes at Bayou Choctaw are dependent on lithology. Faults through loose sands generally dip at 60° while steeper dips occur in the more consolidated sediments. The Heterostegina reef limestone can dip up to 80° particularly near the salt edge, which is technically a fault surface. In the silty, consolidated turbidites of the Frio formation, which is overpressured, dips can range up to vertical. Once the fault has formed, it continues to grow as additional sedimentary layers are deposited as the dome continues to rise. Therefore, the fault offset decreases upward along the fault plane. Although the displacement of some of these dome-related faults is on the order of hundreds of feet, at the dome edge, the faults die out rapidly away from the dome, generally in less than one mile.

Mapping of the dome-related faults at Bayou Choctaw has been based on electric log data. Faults can be interpreted from the logs by correlation of the major stratigraphic horizons such as the "A", 2, 4, 8 and 16 Miocene sands. Absence of stratigraphic offsets of these major units infers faulting. The relatively good well control on and around the Bayou Choctaw dome allows for the faults in one well to be correlated with those in the surrounding wells to determine the orientation of the fault planes. The accuracy of determining the amount of offset depends on the lithology of the sediments through which the fault passes. In shales, for example, the resolution of an electric log is good to within two feet; whereas, in a coarse, cross-bedded levee or channel sands, a fault with 200 feet of offset may be obscured.

The sections isopach and structural maps constructed from the well log data were used to define the subsurface structure surrounding the salt dome. The structure contour maps on the surfaces of the major marker horizons ("A" and Numbers 2, 4, 8 and 16 Sands, Heterostegina Limestone and Frio Formation; Figures 6.12 through 6.18) were drawn to define the salt edge and show the lateral extent of faulting. Since the faults are pushed from the salt, their pattern helps predict the location of the salt dome. The hatched areas on the structural maps show where the key marker units are absent caused by the structural offset of the unit by normal faulting. As can be seen on the structure maps, the extent and magnitude of faulting increases with depth. Fault offsets on the Pliocene are on the order of 50 to 100 feet while those on the Oligocene Heterostegina Limestone are generally over 400 feet. Sections were drawn radially (Figures 6.2 through 6.8 and 6.20) and tangentially (Figures B-1 through B-8) to the dome, in order to orient them normal to the radial and tangential faults. If a section is not oriented normal to the fault, the dip of the fault plane will appear shallower than it actually is. For example, tangential Fault F-1 is intersected at approximately a right angle by radial cross-section B-B' (Figure 6.3) and so the true dip angle of about 60° is shown. A tangential section S-S' (Figure B-7), however, intersects F-1 fault plane at an oblique angle and so the trace of the fault appears nearly horizontal.

Since the motive force for normal (down) faulting comes from growing salt uplift, the sense of motion along the edge of the salt is opposite to that shown by the sediments. Where the sediments show a linear drop on the down (dip) side of the fault, the salt shows a curved updrag in the same direction as indicated on section K-K' through proposed Cavern C (Figure 6.27).

Construction of radial cross-sections is necessary for accurate estimation of the geometry of the salt. The controlling tectonic stresses and resultant salt geometry are observed in the fault patterns which require both radial and tangential sections to define the salt dome in three dimensions.

6.4.2 - Major Dome Faults

Eleven major faults (labelled F-1 through F-11) and numerous minor faults have been defined around the Bayou Choctaw salt dome. Many more small scale faults (displacement in the tens of feet) are likely to exist but are not considered critical to defining the salt dome. Three of the major faults displace the top of the Pliocene sediments and are likely to continue through to the surface. These faults are considered "active" in that they cut Holocene sediments. The remaining faults offset only Miocene and older sediments and are considered "inactive". Active faults are discussed separately below.

The major faults are both radial from and tangential to the dome. The radial faults appear on many of the structure maps to strike through the salt mass, for example, fault F-7 on the "A" Sand structure map strikes out of the northwest and southeast flanks of the dome (Figure 6.12). This is because many radial faults originally formed tangentially to the dome. As the salt dome moved upward, it passed through the fault plane destroying it but leaving traces of the plane away from the dome intact. Table 6.3 lists the major tangential and radial faults.

a. Tangential Faults

i Fault F-4

Fault F-4 strikes N60°W and dips steeply to the northeast. The amount of offset varies considerably. Offsets are greatest near the dome and at depth and die out away from the dome and near the surface. Displacement also depends on the structural relationship with adjacent faults. About 100 feet of offset occurs on the structure map of the "A" sand (Figure 6.12). This increases downward to 200 feet on the Frio formation (Figure 6.18). At the intersection with fault F-3, there is almost 600 feet of displacement.

ii Fault F-5

Fault F-5 on the south side of the salt dome strikes N80°W and dips to the south away from the dome. This fault is a good example of fault growth with depth as shown by structure maps of the "A", No. 2 and No. 4 sands (Figures 6.12, 6.13, and 6.14). On the "A" Sand, the offset is less than 100 feet but increases to nearly 200 feet on the No. 4 Sand. The length and width of the fault trace also increases with depth from 3,400 feet by 100 feet on the "A" sand to 6,500 feet by 140 feet on the No. 4 Sand. The fault plane is off the map on the deeper geologic units. Fault F-5 is shown on section F-F' (Figure 6.7) as coming up under the salt overhang which suggests that the fault may be related to this structure.

iii Fault F-6

Fault F-6 is on the northwest flank of the dome. The fault plane strikes N30°E and dips to the northwest. The offset is quite variable but generally increases from less than 100 feet on the "A" Sand to about 200 feet on the No. 4 Sand (Figure 6.14). The F-6 borders the overhung salt edge on the northwest flank between 3,000 and 1,200 feet where it is truncated by the younger active F-1 fault (Figures B-3 and B-8).

b. Radial Faults

i Fault F-7

The F-7 fault strikes N70°W and dips to the southwest. The fault plane offsets beds to the top of the Miocene. Displacements range from less than 50 feet on the "A" Sand (Figure 6.12) to 400 feet on the No. 8 Sand (Figure 6.15). The F-7 forms the edge of the main salt overhang on the west side of the dome (Figure B-3).

ii Faults F-8 and F-9

Faults F-8 and F-9, which occur on the southeast flank of the dome, strike N10°W. Fault F-8 dips to the west and F-9 dips east. The F-8 fault forms a classic graben-horst structure with the F-9 fault and the F-4 fault to the northeast (Figure 6.12). (The graben is the downthrown block bounded by F-8 and F-9). The F-9 fault has offset beds between the top of the "A" Sand and the No. 8 sand. Displacement varies from about 100 feet on the "A" Sand (Figure 6.12) to 300 feet on the No. 4 sand (Figure 6.14).

iii Fault F-10

The F-10 fault lies on the southwest flank of the dome. The strike and dip are N40°W and southwest, respectively. The F-10 has offset beds from the No. 2 sand to the No. 8 sand (Figures 6.13 and 6.15). Displacements do not significantly change with depth being generally from 100 to 150 feet. This fault is a good example of the transition from tangential to radial fault. The trace of the fault plane on the No. 8 Sand structure map is tangential to the dome. Following the fault plane up-dip to the No. 4 sand (Figure 6.14), where it is intersected by the dome. On section A-A' (Figure 6.2), the salt edge is offset along the traces of the F-10 fault plane and an unnumbered fault below it.

iv Fault F-11

Fault F-11, lying on the southeast flank of the dome, strikes N30°W and dips to the southeast. The F-11 has offset beds to the top of the Miocene No. 8 Sand (Figure 6.15). Displacement is generally 300 to 400 feet.

6.4.3 - Possible Active Faults

Only several of the faults shown on the sections may be considered to be "active" in the terms that they are continuing to grow with increased sedimentation and salt dome uplift. The best evidence for active faulting is fault F-1 on the north side of the dome. Three sections were drawn N15°W out from the dome to cross F-1 at right angles (Section B-B, C-C' and E-E'; Figures 6.3, 6.4, and 6.6). All of these sections pick up 50 feet or more of displacement in Pliocene (Figure 6.9) and shallower sediments. The fault dips to the north away from the dome at 60°. There is a slight salt overhang above where this fault cuts into the salt mass, apparently isolating a block of salt at the northwest corner of the dome. This suggests gravitational instability salt at shallow depths where the salt is denser than the surrounding sediments resulting in the salt starting to break away from the main dome. The fault passes under collapsed Cavern 7 (Section B-B', Figure 6.3). The surface over this broken salt block shows signs of surface subsidence as evidenced by the anomalous meander of the bayou below Cavern Lake (Figure 2.3).

Although the southeast flank fault, F-2, (Figure 6.9) may cut the top of the Pliocene, there is little evidence for its current activity. The F-2 fault appears to cut through the southern caverns (Figure 6.12) which are pressure-tight, suggesting that it is an old fault zone that has been healed by salt creep. There is no large overhang on this side of the dome, except a small complex "bowtie" structure (Figure 6.20) found at approximately a half mile depth where this fault is projected to intersect the dome (see Section 6.3.4).

Another possibly active fault (marked F-3 on Section H-H', Figure 6.20) strikes north-south along the east side of the dome. The fault dips to the east and does not appear to intersect the salt. It has been identified on the top of the Pliocene and appears to reflect the area of maximum salt uplift today, forming the active margin of the dome. Temporary springs were found along this line at the time of the collapse of Cavern 7.

No evidence for active faulting has been found on the west side of the dome either above or below the large overhang. The movement of most of the fault is so slow that salt creep can probably keep ahead of them, at least in the interior of the dome.

6.5 - Temperature-Depth Relationship

In order to show the effect salt structures have on the geothermal temperature gradients, two graphs were constructed (Figure 6.25 A and B). The first graph plots the temperatures measured in the wells in the immediate vicinity of the dome (including those which penetrated salt), and the second plots temperatures in regional wells.

The wide variance in temperatures at equal depths, as noted on the two graphs, is the result of temperature measuring techniques. To achieve a more accurate temperature profile, a well must be left idle for several days (twice the drilling time for shallow holes) after drilling so that the temperatures of the drilling fluid can equilibrate with the surrounding sediments. Because of the high cost of drilling, this procedure is not always followed. Therefore, those temperatures that plot to the left (cooler) are likely from holes that were not equilibrated.

As shown in Figure 6.25A, those wells which either penetrated or are close to the salt edge tend to have higher temperatures than those further away. The average goethermal gradient from ground surface to approximately 8,000 feet is approximately 7°F per 1,000 feet. Below 8,000 feet, the gradient steepens to approximately 11°F per 1,000 feet in the surrounding sediment, and to approximately 30°F per 1,000 feet in the salt. This change in gradient occurs at the major lithologic change from the Miocene sands to the underlying Oligocene shales.

The more permeable Miocene sands tend to dissipate heat more rapidly by circulating groundwater than the more impermeable shales. Therefore, the shales and the salt retain more heat resulting in a higher geothermal gradient. The gradients of these rocks are related to their material properties and thermal conductivity.

The regional data supports this finding. The regional data plotted on Figure 6.25B is primarily from the brine disposal wells south of the site and gas wells north of the site in the Bayou Choctaw Northwest, Port Hudson and False River fields (see Figure 3.2). The temperature gradients from these wells are the same as shown in Figure 6.25A, with the exception that the change in gradient occurs 5,000 feet deeper at a depth of about 13,000 feet. As stated above, this depth corresponds to the contact between the

Miocene sands and Oligocene shales. The contact is higher at the dome as a result of salt dome tectonics which has dragged this contact upwards along the dome boundaries.

Examination of Figure 6.25B shows the Amoco Production Company (AP) wells to have a higher temperature gradient than the deeper Chevron (CH and CO) wells. The Amoco wells are in the Port Hudson field which, based on seismic data, is structurally controlled by a salt ridge. The sediments in the Port Hudson field being closer to the salt have a higher gradient than those in the Chevron wells at the False River field which is stratigraphically controlled.

In summary, the geothermal gradients in and around salt domes are, in part, controlled by the surrounding geology and geohydrology. A comprehensive understanding of the site geology and geothermal gradients allows for a quantification of the salt behavior.

6.6 - Impacts on SPR Facilities

6.6.1 - Introduction

This section summarizes the potential impacts on existing and proposed SPR site facilities resulting from the characterization of the geology and geometry of the Bayou Choctaw salt dome. The impacts of natural hazards are further discussed in Section 7.

6.6.2 - Alternate Cavern Locations

Four potential cavern locations were proposed in previous studies as alternate cavern locations for storage of high pressure ethane by Allied Chemical Corporation. During the contract period special emphasis was given to a geotechnical study of the four locations at the specific request of Sandia National Laboratories.

Location A - Location A is shown on Figure 6.1 with a section through the cavern shown on Figure 6.26, Section I-I'. Based on the interpretation of the salt dome boundary in this area, the proposed Cavern A would intersect the salt boundary at approximately 4,000 feet below the surface. As indicated in Section 6.3.4, salt "inclusions" and disturbed salt may extend up to 300 feet into the salt mass. It is for this reason that a minimum of a 300 foot into the salt mass. It is for this reason that a minimum of 300 foot buffer zone be maintained between any cavern and the dome boundary. In summary, Location A is not considered a viable site for cavern development.

Location B - Location B is shown on Figure 6.1. A cavern located at B is well within the salt dome boundaries. However, the well head and upper casings would be within the zone of possible failure influence from a collapse of Cavern 4 (Tillerson, 1980) (see Section 7.5 and Figure 7.3). Unless measures are taken to stabilize Cavern 4, Location B should not be considered a viable site.

Location C - Location C is shown on Figure 6.1 and sections K-K' and L-L' (Figure 6.27). As shown, an estimated 300 foot salt buffer can be safely projected at the bottom of a sump to a depth of 5,500 feet below ground surface. No geologic features were found in this study that would adversely affect location C as an ethane storage facility.

Location D - Location D is shown on Figure 6.1 and Section J-J' (Figure 6.26) and is found in the northwest corner of the dome in an area of faulted and disturbed salt (see Section 6.3.4). The history of cavern leakage and collapse in this area of the dome causes concern as to the viability of this site for ethane storage. Additional drilling and testing in this area would be required before the site could be fully assessed for cavern development.

6.6.3 - Cavern 20

Cavern 20 is located along the west flank of the dome (Figure 6.1). Section A-A' on Figure 6.2 shows the best estimate of distance to the edge of the salt to be approximately 130 feet. This is consistent with interpretations made by PB/KBB (1978) within the limit of accuracy of available well control. Section A-A' (Figure 6.2) show the salt surface offset by fault F-10 and a deeper, unnumbered fault. These faults may indicate an unstable area of salt near Cavern 20.

6.7 - Cavern Geometry

6.7.1 - Introduction

This section is a summary of available information regarding cavern geometry, condition and present use. The information is based on this study, the work of Parsons Brinkerhoff, Quade and Douglas, Inc./Kavernen Bau-und Betriebs-GmbH (PB/KBB, 1978c) with updates on cavern geometry and volume from the results of recent sonar surveys (Dowell, 1980a and 1980b).

There are at present twenty-five caverns and/or wells with undeveloped caverns penetrating the Bayou Choctaw salt dome. Fifteen of these are within the Department of Energy acquisition.

In addition to caverns in the present DOE acquisition, the other caverns within the Bayou Choctaw dome are discussed briefly as they relate to the DOE storage caverns. Cavern and well locations can be found on Figure 2.3 in Section 2. Cavern profiles based on sonar survey data are presented as Figures 6.28 through 6.41. Each figure shows the most recent east-west and north-south profiles. Where possible, the oldest and latest sonar profile are shown so that a comparison of the changes in cavern geometry can be seen. On the shallow caverns, the salt/caprock, clay and gypsum/massive gypsum-anhydrite and caprock/sediment contacts are shown. These contacts are based on the salt structure map (Figure 6.19) and the structure map the of massive caprock unit (Figure 5.3).

A cavern and brine well summary of pertinent data for all caverns in the Bayou Choctaw dome is presented as Table 6.4.

6.7.2 - Caverns and Brine Wells Within Department of Energy Property

The caverns within the DOE acquisition are discussed below.

Cavern 1

Cavern 1 was drilled in 1937 to a depth of 1,988 feet. As of 1977, the top of the cavern was at a depth of 950 feet and the diameter was, on the average, 250 feet (Figure 6.28). The cavern volume is 8.42 million barrels. The top of the salt over the cavern is at a depth of 579 feet. The salt roof thickness is 371 feet. The cavern is currently inactive.

Previous studies performed by PB/KBB (1978c) recommended a salt roof thickness to cavern span ratio of 1.0 but never to be less than 0.5, to maintain cavern stability. The ratio for Cavern 1 is about 1.5, thus, the cavern is considered structurally stable.

The cavern, however, is not pressure-tight due to undermining of the lower cemented casing with solutioning upward to the caprock. Repair of the well bore and sealing of the cavern was not considered feasible and therefore the cavern was not considered for oil storage or brine production (PB/KBB, 1978c).

Cavern 2

Cavern 2 was drilled in 1934 to a depth of 1,846 feet. The volume of the cavern (calculated from the last sonar survey in 1977) is 9.02 million barrels. The cavern is no longer being brined. The salt roof over the cavern is generally 80 to 100 feet thick (Figure 6.29).

Gulf Interstate Engineering Corporation has certified Cavern 2 for crude oil storage as a "limited service" cavern. PB/KBB (1978c) has rejected the use of this cavern for oil storage based on: the thin salt roof, the poor quality of the caprock, possible fracturing of salt from detrimental pressure variations and risk of oil leakage.

Cavern 3

Cavern 3 was drilled in 1934 to a depth of 2,000 feet. The cavern roof is at a depth of 890 feet, approximately 100 feet below the top of the salt (Figure 6.30). The present volume (based on 1977 sonar data) is 5.01 million barrels. Currently, the cavern is no longer being brined.

Cavern 3 is in pressure communication with Caverns 11 and 13. PB/KBB (1978c) stated that tests indicate that at low pressures, the caverns communicate through salt but at higher pressures a connection through the caprock or caprock/salt contact develops. Sonar surveys show no evidence that the caverns have coalesced.

The cavern was abandoned after a large quantity of ethane was injected and lost into the shallow sands.

Cavern 4

Cavern 4 was drilled in 1935 to a depth of 1,990 feet. The cavern roof (Figure 6.31), at a depth of 620 feet which extends into the massive caprock zone about 40 feet above the top of the salt. The volume of the cavern is 5.94 million barrels based on a 1980 sonar survey. Cavern 4 was abandoned in 1954 after several years of brining by air-lift due to loss of cavern pressure.

The sonar survey run in 1980 (Figure 6.31) shows a significant enlargement of the cavern to the west and upwards from the initial survey in 1963. A detailed discussion of the potential for collapse of Cavern 4 is presented in Section 7.

Allied 5

The Allied Number 5 well was drilled in 1943 to a depth of 775 ft, but was abandoned before leaching began because of local subsidence.

Allied 8

The Allied Number 8 was drilled in 1944 but abandoned due to local susidence. It was replaced by Cavern 8A.

Cavern 8A

Cavern 8A was drilled in 1944 to a depth of 2,007 feet. The top of the cavern (Figure 6.32) is presently at a depth of 1,235 feet, approximately 460 feet below the top of the salt. The most recent (1980) sonar survey shows virtually no change in shape or volume since the 1973 survey. The present volume of Cavern 8A is 3.12 million barrels. Currently, the cavern is not being brined because of a leak in the 10-3/4 inch casing at a depth of about 1,160 feet. Efforts at sealing this zone have failed to date.

The roof-to-span ratio is about 3, indicating a stable condition. Cavern 8 is located far enough from adjacent caverns to permit additional brining or several cycles of oil withdrawal without coalescing with adjacent caverns. If Cavern 8A can be made pressure tight, it would be suitable for brining and/or oil storage (PB/KBB, 1978e).

Allied 9

Allied 9 well was drilled in 1944 to a depth of 2013 feet but was abandoned before leaching began when the casing collapsed due to local subsidence.

Cavern 10

Cavern 10 was drilled in 1947 to a depth of 1942 feet. The present top of the cavern is at a depth of 990 feet and is overlain by over 300 feet of salt (Figure 6.33). The cavern was abandoned when brine returns were lost. This may have resulted from the cavern being leached through the salt to the surrounding sediments. PB/KBB, (1978c) also suggests that alternatively, the loss of pressure may be due to a leak in the casing seat. The volume of the cavern is 6.4 million barrels.

Cavern 11

Cavern 11 was drilled to a depth of 1,928 feet in 1947. Based on the 1980 sonar survey, the cavern top is at a depth of 1,030 feet and is overlain by approximately 350 feet of salt (Figure 6.34). The volume of the cavern is 9.5 million barrels. The cavern is currently inactive. The cavern has enlarged substantially to the west and upward. The cavern roof-to-span ratio is slightly greater than 1 which is considered stable. (See preceeding Cavern 3 section for a discussion of the pressure communication between Caverns 3, 11 and 13).

Allied 12

Allied 12 well was drilled in 1947 to a depth of 2020 ft. The well collapsed and was abandoned before leaching began.

Cavern 13

Cavern 13 is a shallow cavern which was drilled to a depth of 1,915 feet in 1948. The top of the cavern is at a depth of 1,103 feet. Data from the 1977 sonar survey indicates a cavern volume of 4.31 million barrels. Because of the dip of the top of the salt surface (Figure 6.35), the thickness of the salt roof varies north to south from 270 to 190 feet. Assuming an average width of about 230 feet, the cavern roof-to-span ratio is approximately 1 and so this cavern is considered stable. (See Cavern 3 section for discussion of the pressure communication between Caverns 3, 11 and 13).

Cavern 15

Cavern 15 was drilled in 1953 to a depth of 3,357 feet. The top of the cavern (Figure 6.36) is at a depth of 2,597 feet which is 1,960 feet below the top of the salt. The volume of the cavern, calculated from the 1974 sonar survey is 16.6 million barrels. Cavern 15 is presently being used to store crude oil and contains approximately 8 million barrels. With the present thick salt roof and cavern shape, Cavern 15 is considered stable.

Allied Chemical's nearby Cavern 17 is presently being used to store ethane under high pressure (up to 2000 psi) and to strengthen brine. Figure 6.37 is an east-west section through Caverns 15 and 17. Because of this ongoing operation, and the lack of recent sonar data, it is difficult to accurately determine the thickness of the salt web between the two caverns. It is likely that the actual thickness between the two caverns is between 100-200 feet.

Cavern 18

Cavern 18 is a deep cavern that was drilled in 1967 to a depth of 4,383 feet. Based on the 1978 sonar survey, the cavern roof is at a depth of 2,100 feet which is over 1,200 feet below the top of the salt. The present volume of the cavern is 8.5 million barrels. Figure 6.38 shows cavern profiles from the 1971 and 1978 sonar surveys. The cavern has nearly tripled in size between surveys. Based on cavern shape, roof thickness, distance from adjacent caverns and the edge of the dome, Cavern 18 is considered stable. Approximately 4 million barrels of oil are currently in storage in this cavern.

Cavern 19

Cavern 19 is a deep cavern drilled to 4,400 feet in 1967. The cavern top was measured at a depth of 2,980 feet during the 1977 sonar survey (Figure 6.39). The top of the salt is at a depth of 850 feet which leaves a salt roof thickness of over 2,100 feet. The volume of the cavern is 7.46 million barrels. Cavern 19 has sufficient roof and salt web thickness and a favorable cavern shape so that it is considered stable. Approximately 5 million barrels of oil are currently in storage in this cavern.

Cavern 20

Cavern 20 is a deep cavern drilled to a depth of 4,452 feet in 1970. The top of the cavern is presently at 3,935 feet, approximately 3,200 feet below the top of the salt (Figure 6.40). The 1978 sonar survey data indicates that the cavern volume is 5.2 million barrels. The cavern is considered stable with respect to roof thickness and cavern shape. However, the cavern is estimated to be within approximately 130 feet from the edge of the dome under the west flank overhang (see Section 6.6.3 and Figure 6.2).

6.7.3 - Caverns and Brine Wells Outside Department of Energy Property

The caverns and brine wells currently on Allied Chemical Corporation's property are discussed below.

Cavern 6

Cavern 6 (Allied 6) is a small cavern drilled in 1943 to a depth of 2,007 feet. The top of the cavern as well as the top of the salt are not known. The cavern volume is estimated to be less than 100,000 barrels. The original cavern was abandoned due to a high magnesium content in the brine. Currently Allied is planning to expand Cavern 6 to less than 1 million barrels for the storage of product. Further development of the cavern should not affect the DOE facility (PB/KBB, 1978c).

Cavern 7

Cavern 7 was drilled in 1942 to a depth of 1,951 feet. The depth to the original top of the cavern is not known. The cavern volume was calculated from production data to be 2.9 million barrels. Normal brining operations continued into the early 1950's when cavern pressure was lost. It is assumed that presure was lost when the cavern roof was leached to the top of the salt. Brining continued by the airlift method until January, 1954 when the cavern collapsed. This resulted in the formation of a crater about 800 feet in diameter which filled with water and is now called Cavern Lake. Cavern collapse resulted from leaching of the salt to the salt/caprock contact followed by the failure of the caprock and overlying sediments.

Cavern 14

The Allied cavern 14 was drilled in 1953 to a depth of 3,057 feet. The depth to the top of the cavern is not known. The cavern was leached for a short period of time and then abandoned because of high magnesium content in the brine. The cavern volume was estimated to be less than 100,000 barrels.

Cavern 16

Cavern 16 was drilled in 1954 to a depth of 3,408 feet. The depth of the top of the cavern is 2,620 feet. The cavern is overlain by about 1,400 feet of salt. The estimated cavern volume in 1976 was 9.1 million barrels. Currently, Allied is storing ethylene in Cavern 16. Cavern 16 is considered stable based on the thick salt roof.

Cavern 17

Cavern 17 was drilled to a depth of 4,125 feet in 1955. The top of the cavern is at a depth of 2,590 feet and is overlain by approximately 1,900 feet of salt (Figure 6.41). The volume of the cavern, estimated in 1976, is 12.2 million barrels. Currently, Allied is storing ethane under high pressure in Cavern 17. The cavern roof is stable; however, the salt web thickness between Caverns 17 and 15 may be between 100-200 feet. See Section 6.7.2, Cavern 15 for further discussion.

Caverns 24 and 25

Caverns 24 and 25 were both drilled in 1979 to replace caverns taken by DOE. They are both currently shut-in awaiting the need for brine.

Caverns J 1, N 1 and UTP 1

Caverns J 1, N 1 and UTP 1 are small caverns drilled between 1967 and 1972 to depths below 3,500 feet. The depths to the tops of J 1 and N 1 are 2,850 feet and 2,670 feet respectively. The depth to the top of UTP 1 is unknown. The volume of each cavern is less than 1 million barrels. Ethylene is currently being stored in each of these caverns.

TABLE 6.1

BAYOU CHOCTAW SPR SITE
PLIOCENE AND MIOCENE GEOLOGIC UNITS

Age	Formation	Map Symbol	Stratigraphic Unit	Biostratigraphic Zone	Sediment Type	Depositional Environment	Transport Mode	Related Structure/Thickness	Depths to Top: High on Dome (ft)	Depths to Top: Away from Dome (ft)
PLIOCENE	Goliad				Sand over clay	Alluvial levee and backswamp	River channel		Extrapolated on top - 550 approx.	1050 to northwest
		M		Buliminella	Sand over shale	Alluvial levee	Silty mud/overbank			1500
		LP	Lower		Sand over shale	Alluvial levee and backswamp				2395 in Callery-Schwing
MIOCENE	Fleming			Robulus E	Shale	Backswamp		Not mapped - Difficult to correlate. Major oil seal for field		3155 in Callery-Schwing
	Catahoula	A	Clovelly		Sand	Delta	Distributary channel	See Note 1	2550 on east side	3750 in Delta No. 2
		1			Sand	Delta	Distibutary channel			2800 at Baton Rouge
		2			Sand	Delta	Beach/bar		2450 at north end	4500 in Callery-Schwing
		3			Sand	Delta	Beach/bar			5245 in Callery-Schwing
		4	Duck Lake	Bigenerina humblei	Sand	Delta	Distributary channel		3050 on east side	5735 in Callery-Schwing
		AB		Amphistegina B	Shale	Marine transgression	Suspended mud			5900 in Weaver-Wilberts
		5	Duck Lake		Sand	Delta	Distributary channel			6600 in Callery-Schwing
		6			Sand	Delta	Beach/bar	Stratigraphic oil trap		6840 in Callery-Schwing
		7			Sand	Delta	Distributary channel			7375 in Callery-Schwing
		8	Napoleonville	Discorbis bolivarensis	Sand	Delta	Shoreline beach/bar		4650 on north side	7565 in Callery-Schwing
		9			Sand	Fringe bar			7885 in Callery-Schwing	
	SD			Siphonina davisi	Shale	Marine transgression				7800 in Callery-Schwing
		10			Sand	Delta	Shoreline beach/bar			8000 in Callery-Schwing
		11			Sand	Delta	Distributary channel			8150 in Callery-Schwing
		12			Sand	Delta	Distributary channel			8360 in Callery-Schwing
		13			Sand	Delta plain	Levee sheet work			8450 in Callery-Schwing
		14			Sand	Delta fringe	Channel			8635 in Callery-Schwing
		15			Sand	Delta fringe	Channel			8848 in Callery-Schwing
		16		Planulina palmerae	Sand	Delta fringe	Distributary channel	5450 on SE side		9028 in Callery-Schwing
		17			Sand	Deltaic plain	Beach/bar			9260 in Callery-Schwing
		18			Sand	Delta fringe	Offshore bar			9620 in Callery Schwing

NOTES:

(1) Deepest municipal drinking water supply is at 4100 feet in Callery Schwing

Table 6.2
BAYOU CHOCTAW SPR SITE
OLIGOCENE GEOLOGIC UNITS

Age	Formation	Map Symbol	Stratigraphic Unit	Biostratigraphic Zone	Sediment Type	Depositional Environment	Transport Mode	Related Structure/Thickness	Depths to Top: High on Dome (ft)	Depths to Top: Away from Dome (ft)
OLIGOCENE		H		Heterostegina sp.	Reef limestone	Coral atoll around salt dome	Clear water, organic precipitate	Large faults close to salt (see Note 1)	6350 on southeast side	9812 in Callery-Schwing
		MH		Marginulina howei	Thick erratic sand	Shelf edge	Turbidity current proximal end	Block slumps on top of continental slope		10020 in Callery-Schwing
	Anahuac	A			Shale	Deep water	Pelagic & suspended mud	Overpressured		10030 in Callery-Schwing
	Frio	F	Upper		Sand	Deep water	Turbidity current	Slumps, see Figure 6.3	6750 on SE flank	10430 in Callery-Schwing
		MG		Miogypsinoides sp.	Sand	Deep water	Turbidity current	Slumps	Approximately 7000	10800 in Callery-Schwing
		CH		Cibicides hazzardi	Sand	Deep water	Turbidity current	Slumps	Approximately 7500	11045 in Callery-Schwing
		MT		Marginulina texana	Sand	Deep water	Turbidity current	Slumps	7718 in Carter-Gay Union #19	11532 in Alcoa-A. Wilberta Sons
		BM	Hackberry	Bolivina mexicana	Sand	Embayment	Turbidity current	Slumps near toe	8290 in Carter-Gay Union # 11	11870 in Alcoa Unit #11
		NB	Lower	Nodosaria blanpiedi	Tight, dirty sand	Embayment of Sigsbee Deep	Turbidity current; distal end		8705 in Carter-Gay Union #11	12205 in Alcoa well
	Vicksburg			Textularia warreni	Black shale	Pelagic/ocean floor	Suspension & bloom	Uplifted with salt	Probably not penetrated except in sheath	Probably near 13600 in Alcoa well

NOTES: (1) The Heterostegina (Het.) lime is used for waste disposal by the Ethyl Corporation on the north side of the Bayou Choctaw dome. The Ethyl Corp. bought the abandoned P.R. Rutherford, HEP Development Co. #2 well which encountered 120 feet of Het. Lime at a depth of 9,050 feet. The top fifty feet shows excellent vugular or cavernous porosity on the log. It apparently takes some 150 barrels/day on vacuum.

Reefs in the Het. lime are interval characteristic of domes in this area. Up to 400 feet of lime have been found at the White Castle dome. 40 feet of lime are recorded in the CLAW (Clean Land Air Water) well originally drilled as the Hunt Industries Schwing State Land 1833 #1, which has been used for toxic waste disposal.

(2) The underlying Anahuac shale of Oligocene age is overpressured and thicker and contains more volcanic ash than the Miocene shales. Deeper limes or sands are thin and contain large amounts of hydrocarbons, particularly natural gas under excess pressure. The Anahuac is known for its high pressure instability. The enclosed MH and Frio sands are essentially floating on the water still trapped within these organic-rich muds. The shales' permeability is very low, so that despite the weight of overlying sediments, compaction can occur only as the trapped fluid (40% water with gas) escapes through faults. This has caused the growth of faults and some of the complex structures found in the deeper Oligocene. Over 10,000 feet of shale underly the brine disposal site. The remainder of the sedimentary column, including the original salt beds, has not been reached by drilling south of False River.

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TABLE 6.3

BAYOU CHOCTAW SPR SITE
MAJOR FAULTS

Type of Fault	Strike	Dip	Beds Offset To
TANGENTIAL FAULTS			
F-1	N80°E	N	Surface
F-2	N60°E	SE	Surface
F-3	N-S	E	Surface
F-4	N60°W	NE	Top of Miocene
F-5	N80°W	S	Top of Miocene
F-6	N30°E	NW	Top of Miocene
RADIAL FAULTS			
F-7	N70°W	SW	Top of Miocene
F-8	N10°W	W	Top of Miocene
F-9	N10°E	E	Top of Miocene
F-10	N40°W	SW	Top of No. 2 Sand
F-11	N30°W	NE	Top of No. 8 Sand (lower Miocene)

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TABLE 6.4

BAYOU CHOCTAW SPR SITE
CAVERN AND BRINE WELL SUMMARY

Cavern or Well No.	Dated Drilled	Initial Drilled Depth ft.	Depth to top of Cavern ft. (Date)	Gross Volume 10^6 bbl (Date)	Present Use of Status	Remarks
1*	1937	1988	950 (1977)	8.42 (1977)	Idle	Not pressure tight and not repairable.
2*	1934	1846	715 (1977)	9.02 (1977)	Idle	Thin salt roof.
3*	1934	2000	890 (1977)	5.01 (1977)	Idle	Pressure communicates with Nos. 11 and 13.
4*	1935	1990	620 (1980)	5.94 (1980)	Abandoned	Leached into cap rock. Permanent facilities sited within possible zone of cavern failure.
5*	1943	775	--	--	Abandoned	Never completed, cratered. No cavern.
6	1943	2007	Unknown	<0.1 (Est)	Developing for storage by Allied Chemical	Previously undeveloped cavern. Abandoned because of high magnesium.
7	1942	1951	--	--	Collapsed	Collapsed forming lake, January 1954.
8A*	1944	2007	1235 (1980)	3.12 (1980)	Idle	Not pressure tight. Replacement for abandoned Well No. 8.
9*	1944	2013	--	--	Abandoned	Casing collapsed, localized subsidence. No cavern.
10*	1947	1942	990 (1973)	6.4 (1973)	Idle	Not pressure tight. Uncertain source of leakage. Caustic waste believed disposed in well.
11*	1947	1928	1030 (1978)	9.5 (1978)	Idle	See No. 3. Operated with No. 13 in 1972. Sonar volume in 1972 was 10.5 mm bbl.
12*	1947	2020	--	--	Abandoned	Well collapsed. Localized subsidence. No cavern brined.
13*	1948	1915	1103 (1977)	4.31 (1977)	Idle	See No. 3. Operated with No. 11 in 1972.
14	1953	3057	Unknown	<0.1 (Est)	Abandoned	Mined for short period at two depths. Abandoned because of high magnesium.
15*	1953	3357	2597 (1974)	16.6 (1974)	Storing	Storing 11.6 mm bbl.

TABLE 6.4 (Cont'd)

BAYOU CHOCTAW SPR SITE
CAVERN AND BRINE WELL SUMMARY

Cavern or Elv. No.	Dated Drilled	Initial Drilled Depth ft.	Depth to top of Cavern ft. (Date)	Gross Volume 10^6 bbl (Date)	Present Use of Status	Remarks
16	1954	3408	2620	9.1 (Est. 1976)	Storing ethylene	Volume 8.8 x 10^6 bbl. Sonar in 1968, prior to storing ethylene.
17	1955	4125	2590	12.2 (Est. 1976)	Storing ethane	Volume 10.1 x 10^6 bbl. Sonar in 1972, prior to storing ethane. See No. 15.
18*	1967	4383	2100 (1978)	8.54 (1978)	Storing Crude Oil	3.8 mm barrels of crude.
19*	1967	4400	2980 (1977)	7.46 (1977)	Storing Crude Oil	5.1 mm barrels.
20*	1970	4452	3935 (1978)	5.25 (1978)	Intermittant Brining	Cavern close to flank of dome.
24	1979	--	--	--	Idle	No data available
25	1979	--	--	--	Idle	No data available
J 1	1972	3938	2850 (1973)	0.7 (1973)	Storing ethylene	Storage since January 1974.
N 1	1972	3593	2670 (1972)	0.5 (1972)	Storing ethylene	Storage since January 1973.
UTP 1	1967	3800	Unknown	0.7 (?)	Storing ethylene	No sonar caliper. Storage since February 1968. Washing to increase size.

NOTES: a) Volumes are as determined by sonar measurements unless noted.
b) * indicates within DOE property.
c) Top of cavern is highest part of cavern as determined by inspection of sonar surveys.

Reference: PB/KBB, 1978c; Dowell, 1980a and 1980b.

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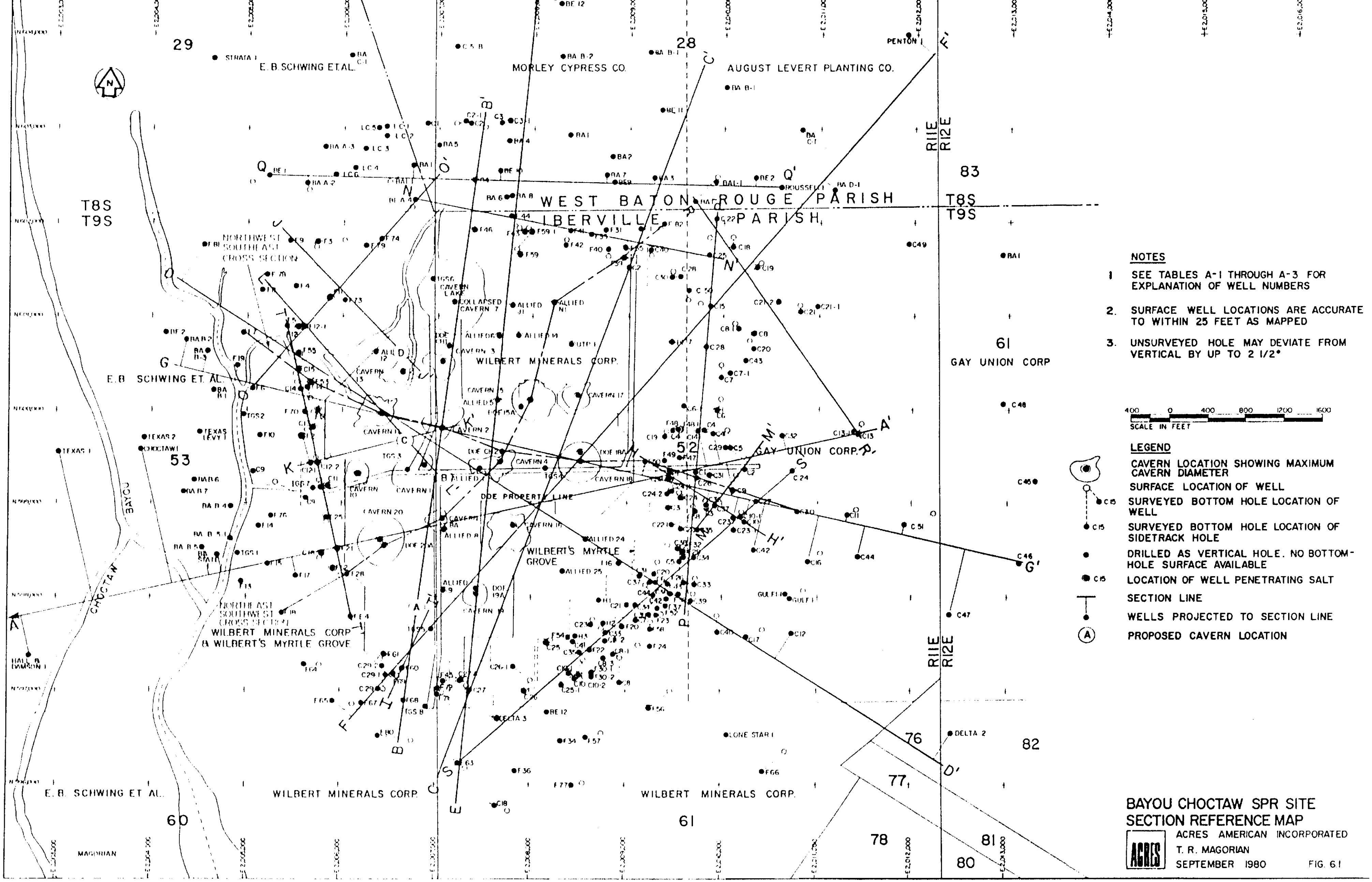
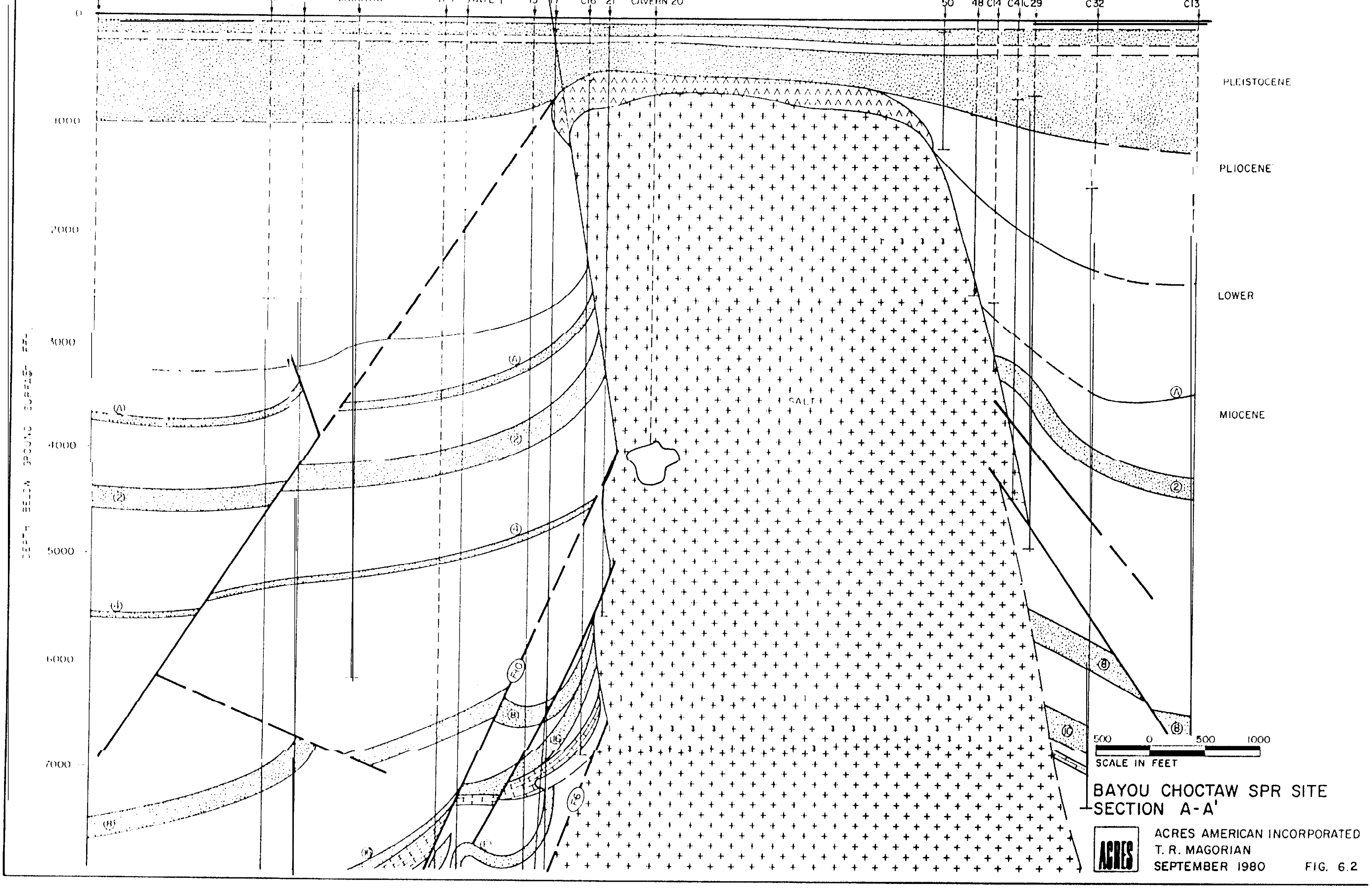


BAYOU CHOCTAW SPR SITE
SECTION REFERENCE MAP
ACRES AMERICAN INCORPORATED

FIG. 61



CAVERN 20
C18
21
15
17
50
48
C14
C41
C29
C32
C13
PLEISTOCENE
PLIOCENE
LOWER
MIOCENE
DEPTH BELOW GROUND SURFACE FT.
0
1000
2000
3000
4000
5000
6000
7000
SALT
500
0
500
1000
SCALE IN FEET
BAYOU CHOCTAW SPR SITE
SECTION A-A'
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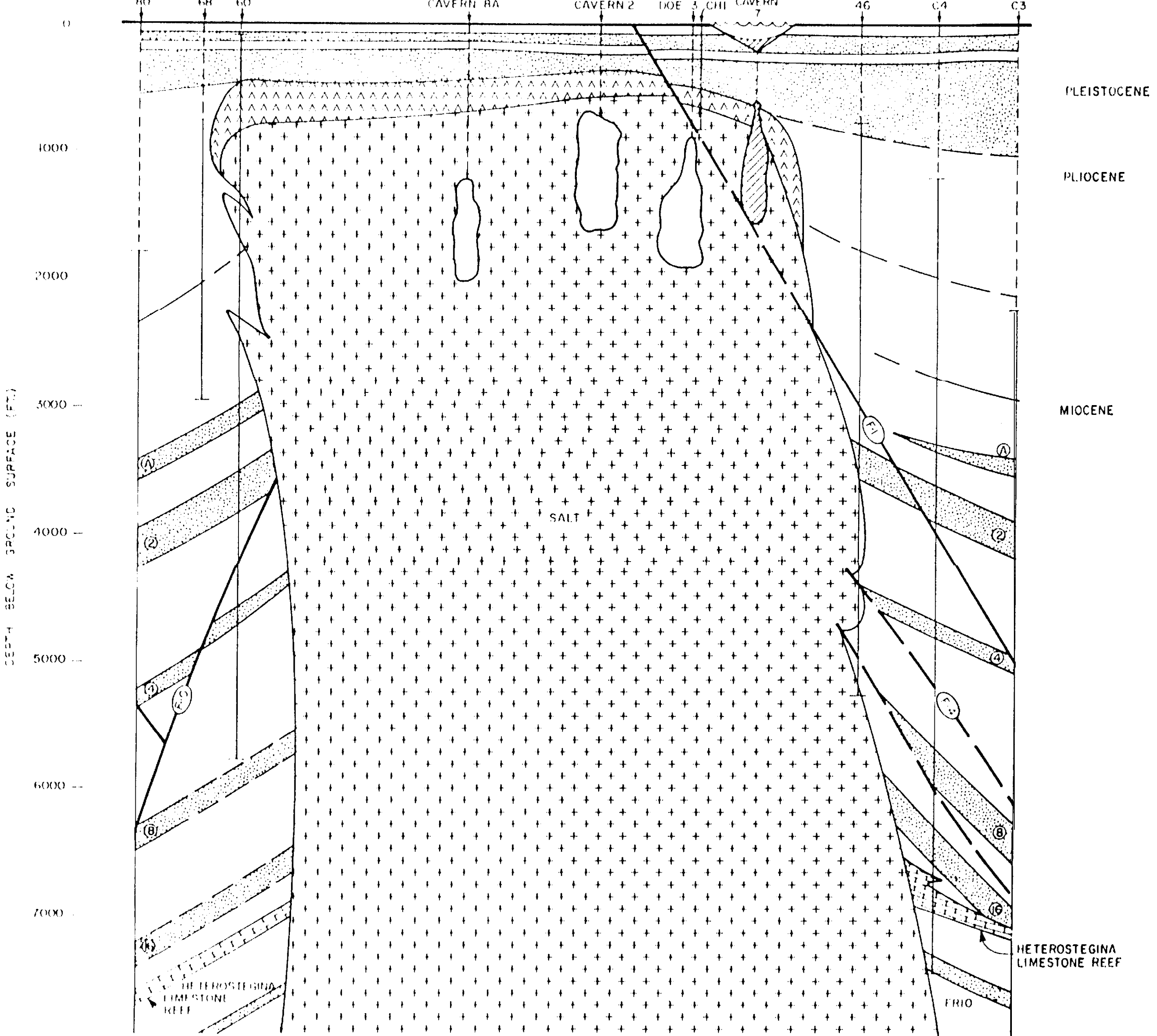
SEPTEMBER 1980
FIG. 6.2



500 0 500 1000
SCALE IN FEET

BAYOU CHOCTAW SPR SITE
SECTION B-B'

ACRES

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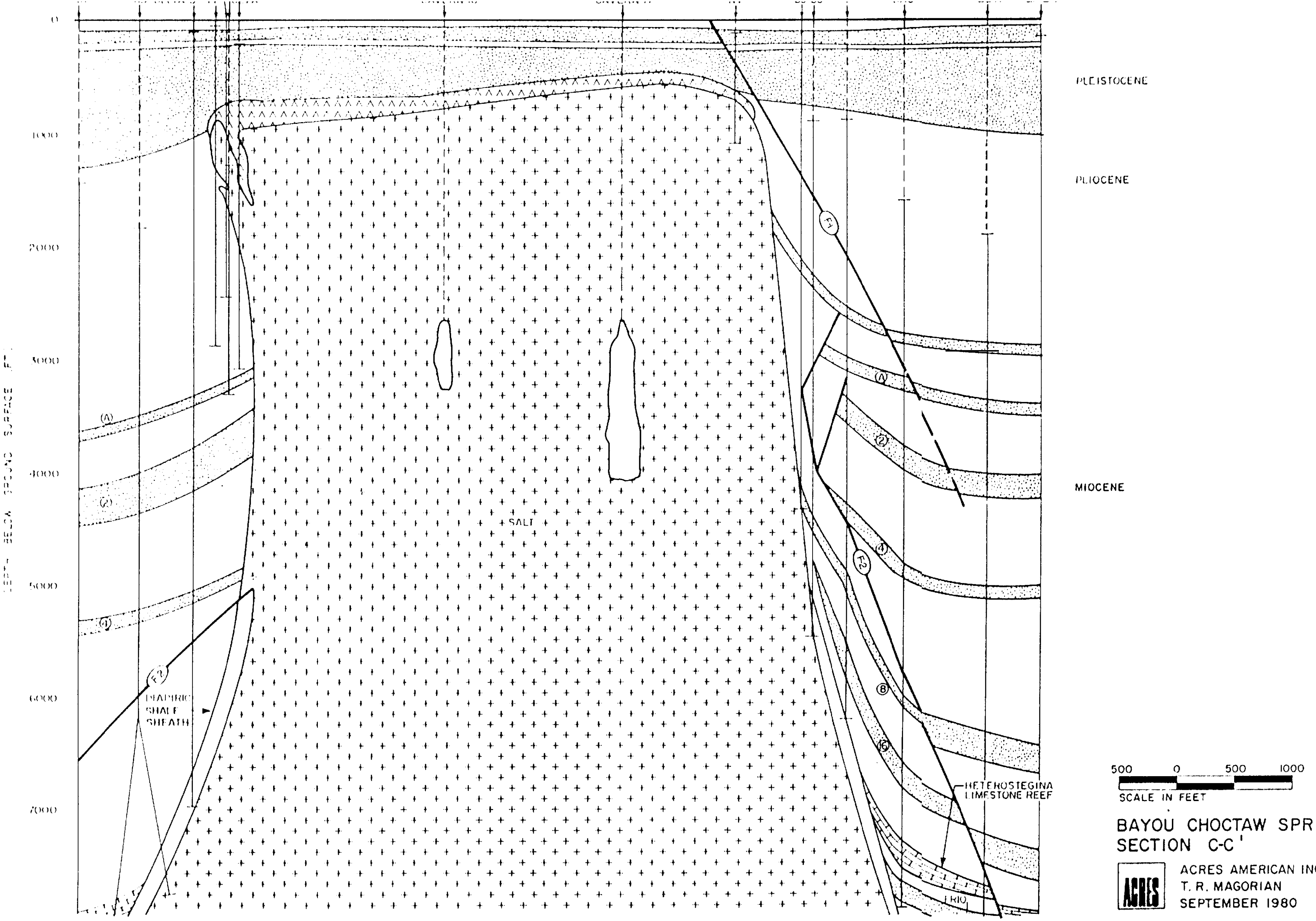
FIG S.3



BAYOU CHOCTAW SPR SITE
SECTION C-C'

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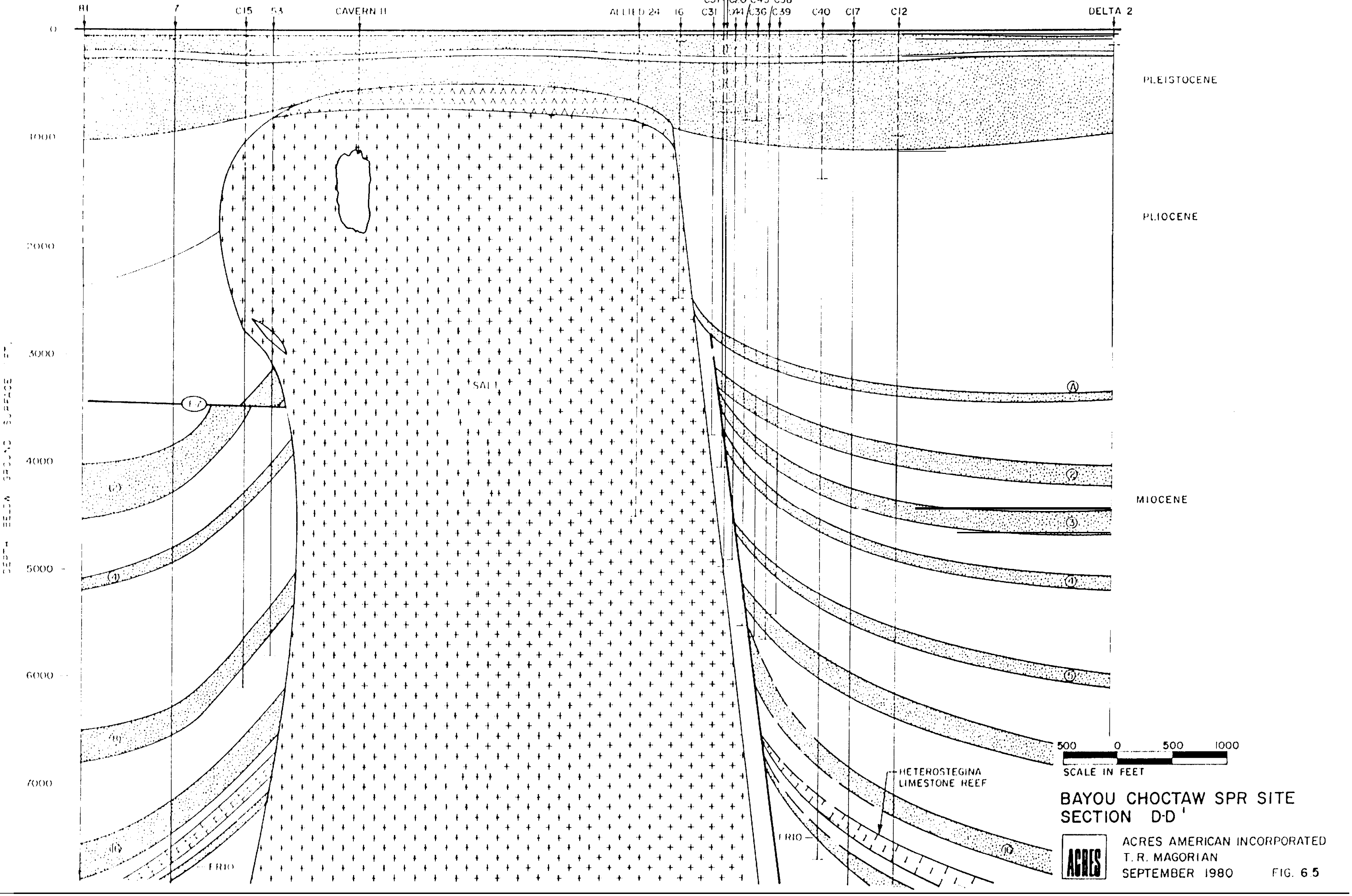
FIG. 6.4



BAYOU CHOCTAW SPR SITE
SECTION D-D'

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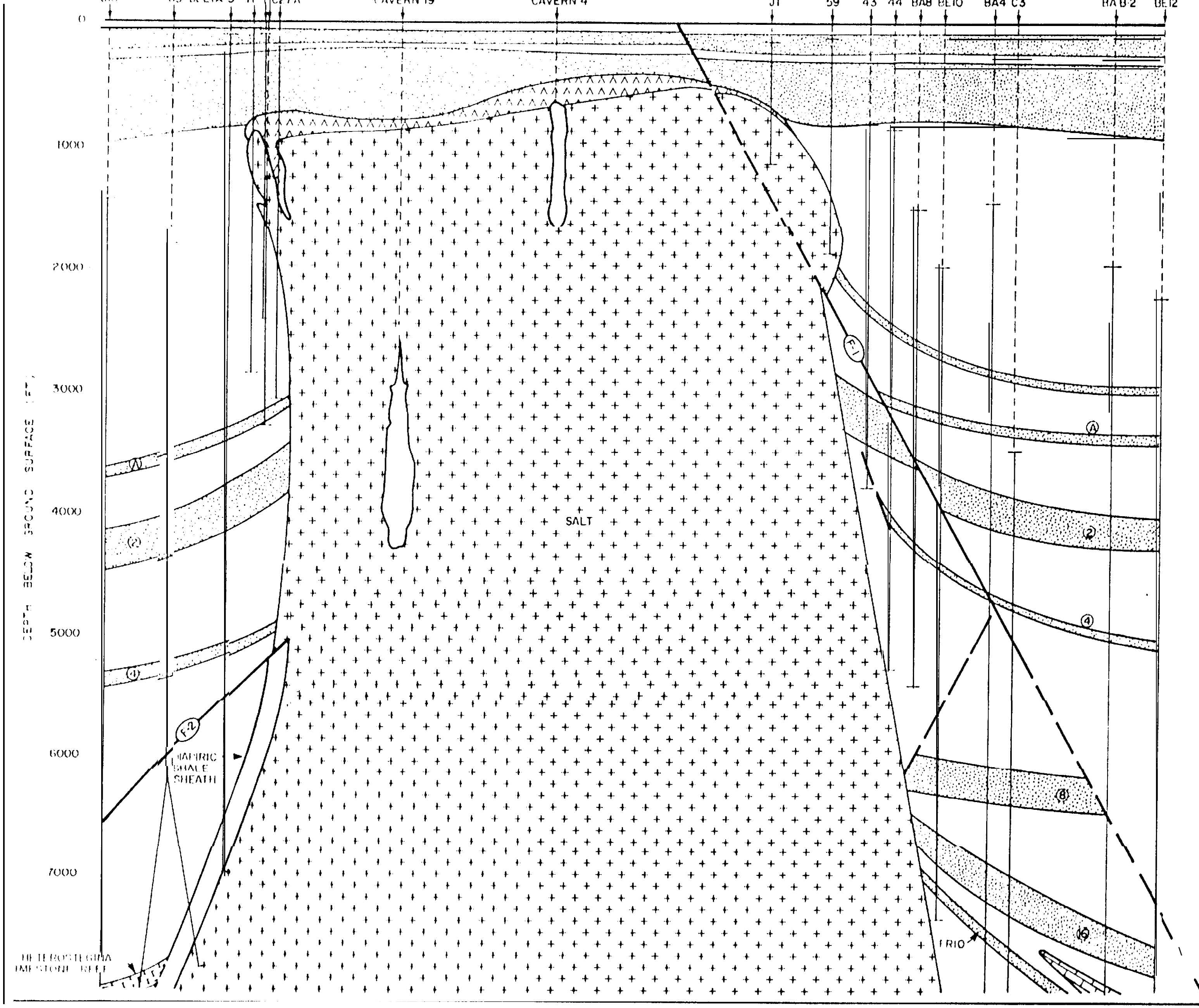
FIG. 65



BAYOU CHOCTAW SPR SITE
SECTION J-3

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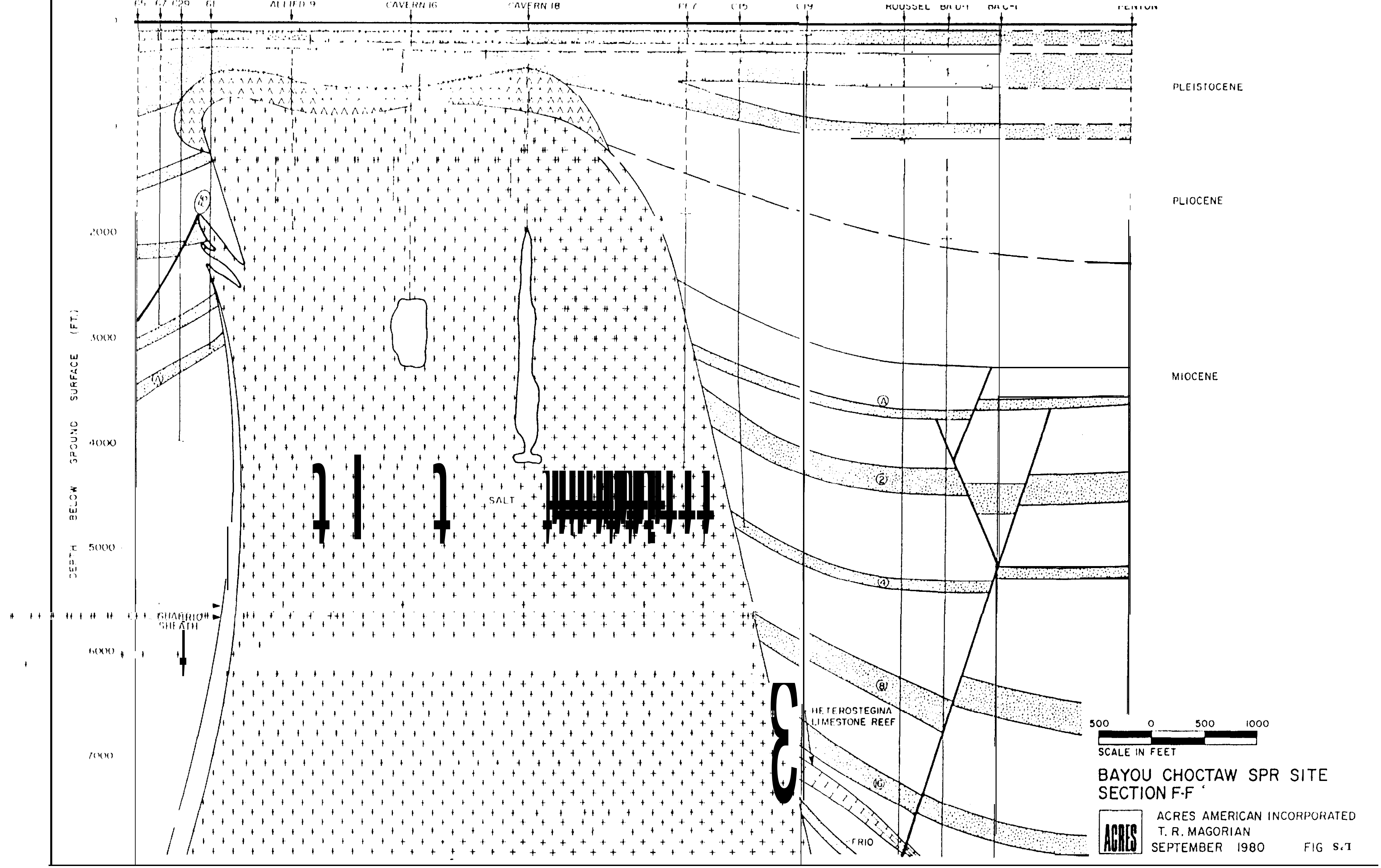
FIG. 6.6



BAYOU CHOCTAW SPR SITE
SECTION F-F'

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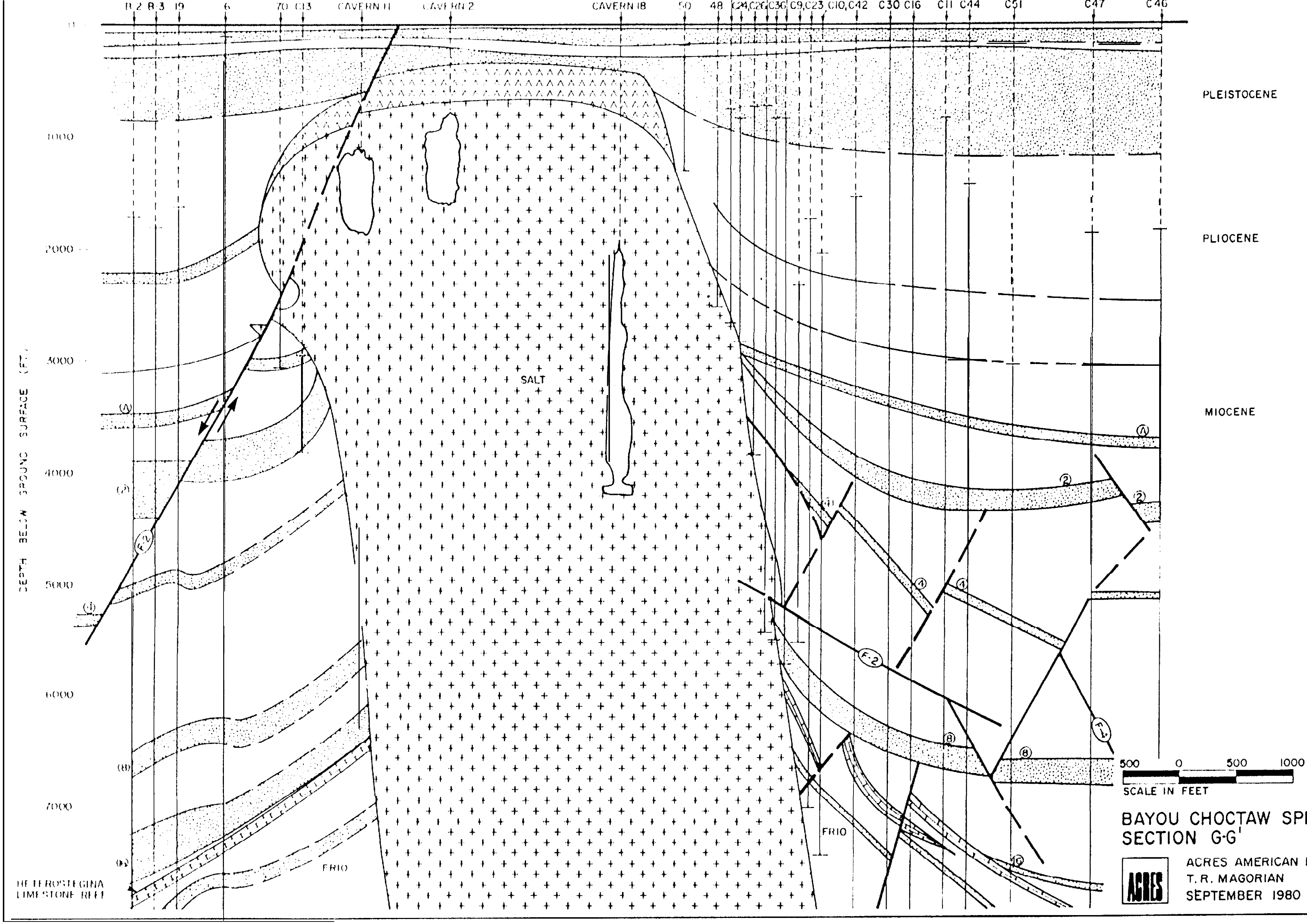
FIG 5.1



BAYOU CHOCTAW SPR SITE
SECTION G-G'

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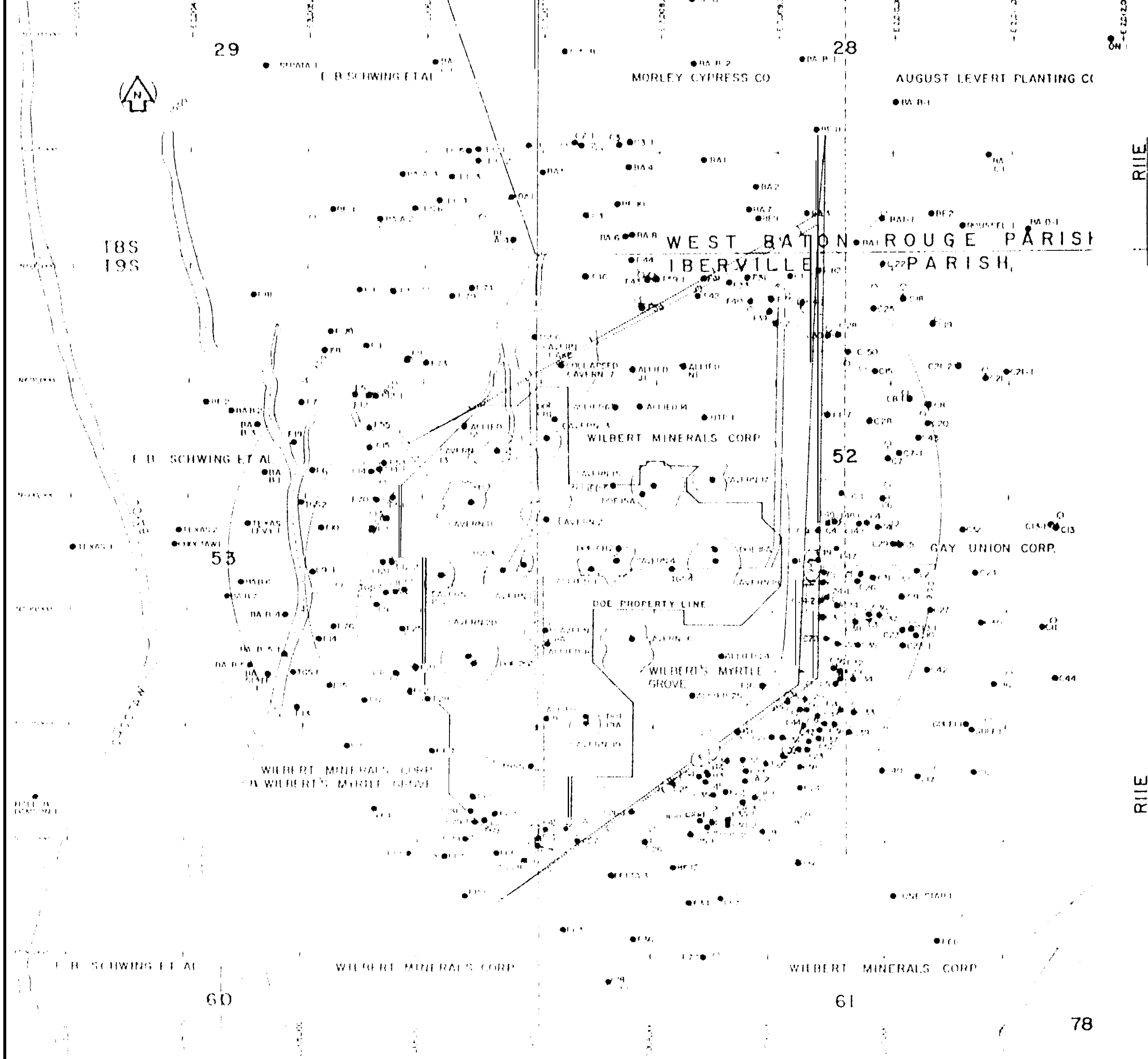
FIG. 6.8



NOTES

1. SEE TABLES A-1 THROUGH A-3 FOR EXPLANATION OF WELL NUMBERS
2. SURFACE WELL LOCATIONS ARE ACCURATE TO WITHIN 25 FEET AS MAPPED
3. UNSURVEYED HOLE MAY DEVIATE FROM VERTICAL BY UP TO 2 1/2°
4. CONTOURED DEPTHS MEASURED IN FEET BELOW DRILLING FLOOR

400 0 400 800 1200 1600
SCALE IN FEET

LEGEND

- CAVERN LOCATION SHOWING MAXIMUM CAVERN DIAMETER
- SURFACE LOCATION OF WELL
- C15 SURVEYED BOTTOM HOLE LOCATION OF WELL
- C15-1 SURVEYED BOTTOM HOLE LOCATION OF SIDETRACK HOLE
- DRILLED AS VERTICAL HOLE, NO BOTTOM-HOLE SURVEY AVAILABLE
- C15 LOCATION OF WELL PENETRATING SALT
- STRUCTURAL OFFSET OF FORMATION CAUSED BY FAULT DISPLACEMENT
- F2 REFERENCED FAULT DISCUSSED IN TEXT
- DEPTH CONTOURS IN FEET

BAYOU CHOCTAW SPR SITE
STRUCTURE ON TOP OF
PLIOCENE SHALE

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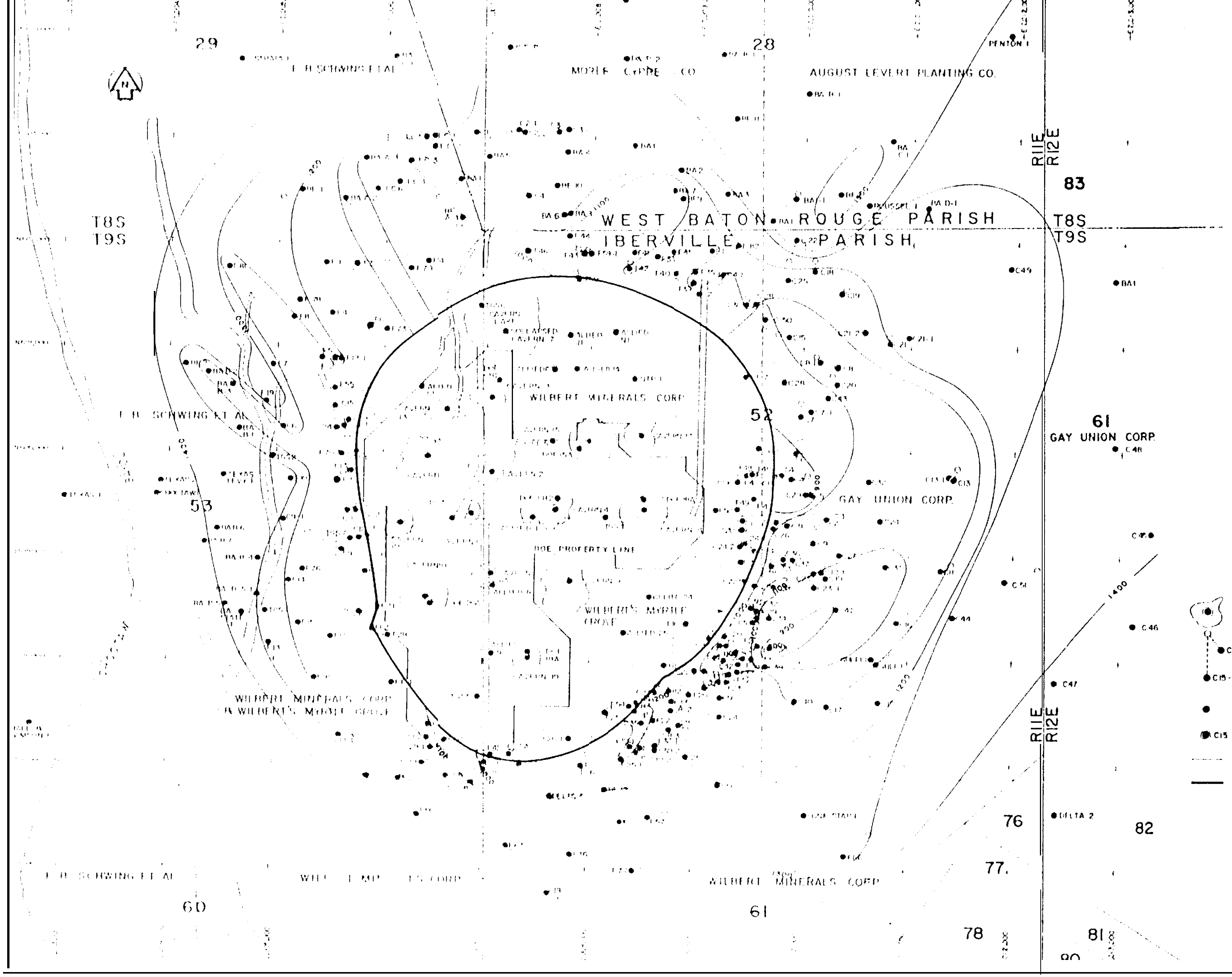
SEPTEMBER 1980 FIG 6.9



NOTES

1. SEE TABLES A-1 THROUGH A-3 FOR EXPLANATION OF WELL NUMBERS
2. SURFACE WELL LOCATIONS ARE ACCURATE TO WITHIN 25 FEET AS MAPPED
3. UNSURVEYED HOLE MAY DEVIATE FROM VERTICAL BY UP TO 2 1/2°

400 0 400 800 1200 1600
SCALE IN FEET

LEGEND

CAVERN LOCATION SHOWING MAXIMUM CAVERN DIAMETER
SURFACE LOCATION OF WELL
C15 SURVEYED BOTTOM HOLE LOCATION OF WELL
C15-1 SURVEYED BOTTOM HOLE LOCATION OF SIDETRACK HOLE
DRILLED AS VERTICAL HOLE, NO BOTTOM-HOLE SURVEY AVAILABLE
C15 LOCATION OF WELL PENETRATING SALT
100 FOOT ISOPACH CONTOUR
CONTACT WITH SALT

BAYOU CHOCTAW SPR SITE
ISOPACH OF MIOCENE-PLIOCENE SHALE

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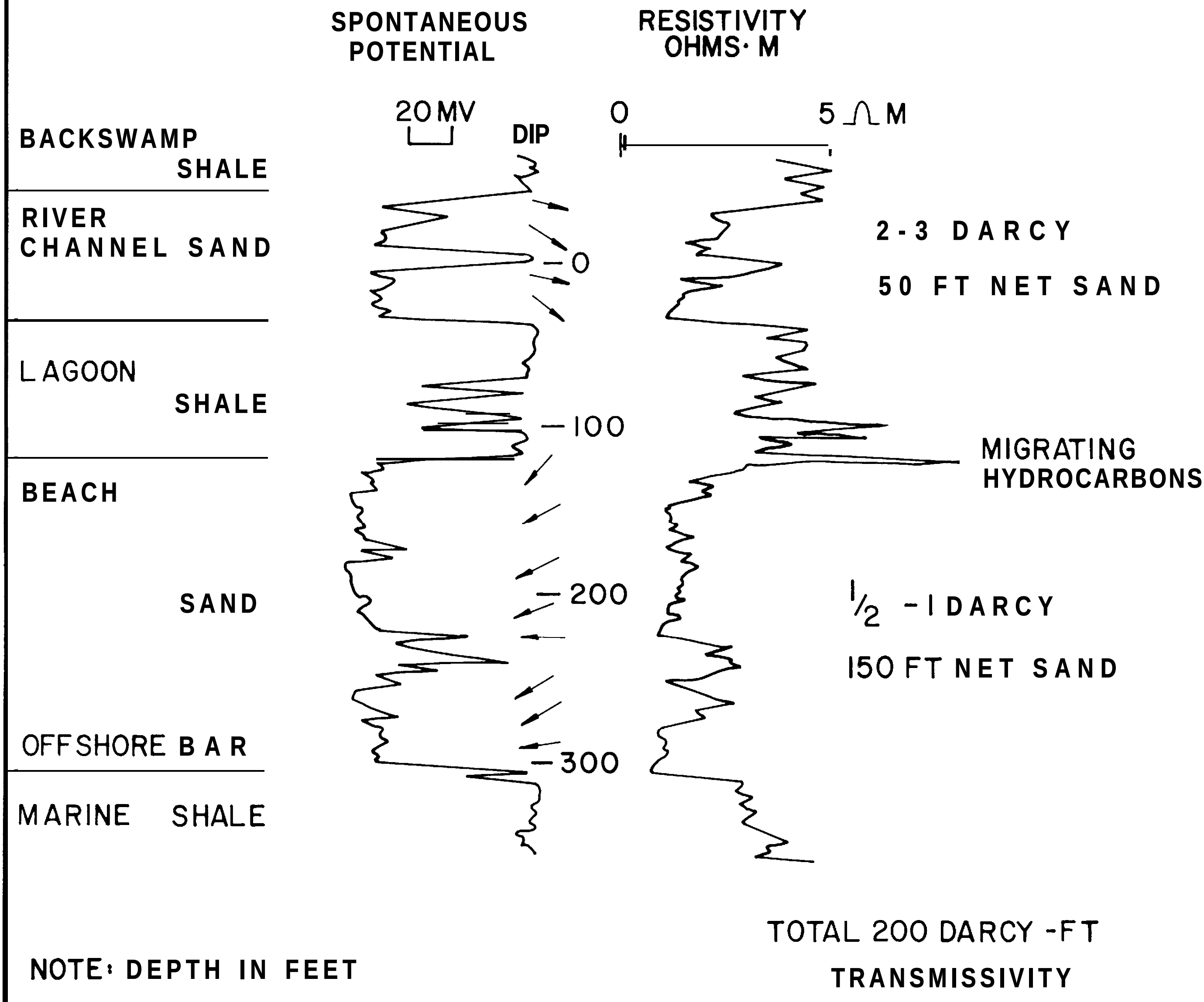

BAYOU CHOCTAW SPR SITE
MIOCENE SAND TYPES

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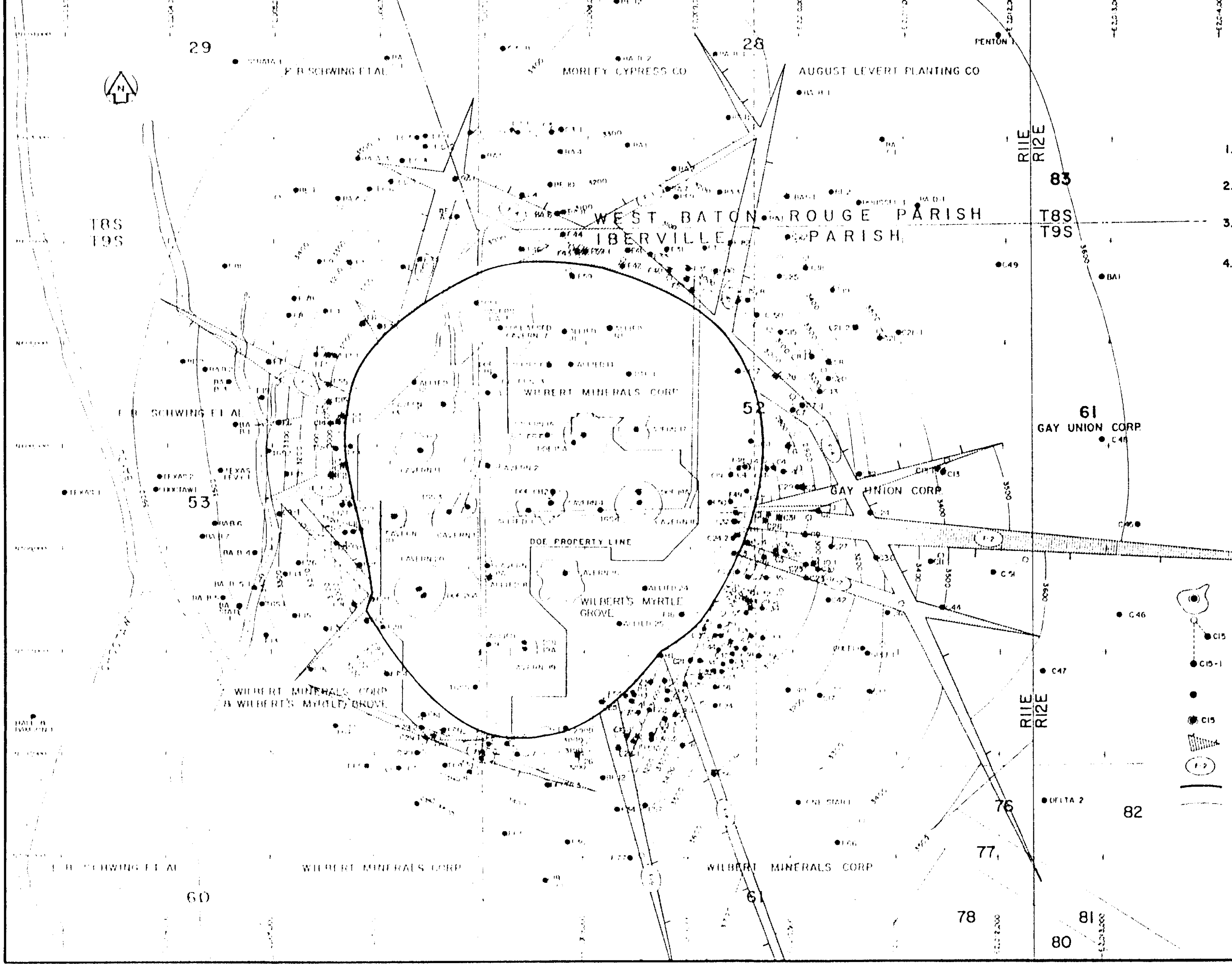
SEPTEMBER 1980

FIG. 6.11



NOTES

1. SEE TABLES A-1 THROUGH A-3 FOR EXPLANATION FOR WELL NUMBERS
2. SURFACE WELL LOCATIONS ARE ACCURATE TO WITHIN 25 FEET AS MAPPED
3. UNSURVEYED HOLE MAY DEVIATE FROM VERTICAL BY UP TO 2 1/2°
4. CONTOURED DEPTHS MEASURED IN FEET BELOW DRILLING FLOOR

LEGEND

- CAVERN LOCATION SHOWING MAXIMUM CAVERN DIAMETER
- SURFACE LOCATION OF WELL
- C15 SURVEYED BOTTOM HOLE LOCATION OF WELL
- C15-1 SURVEYED BOTTOM HOLE LOCATION OF SIDETRACK HOLE
- DRILLED AS VERTICAL HOLE. NO BOTTOM-HOLE SURVEY AVAILABLE
- C15 LOCATION OF WELL PENETRATING SALT
- STRUCTURAL OFFSET OF FORMATION CAUSED BY FAULT DISPLACEMENT
- F-2 REFERENCED FAULTS DISCUSSED IN TEXT
- CONTACT WITH SALT
- DEPTH CONTOURS IN FEET

BAYOU CHOCTAW SPR SITE
STRUCTURE ON TOP OF
"A" SAND

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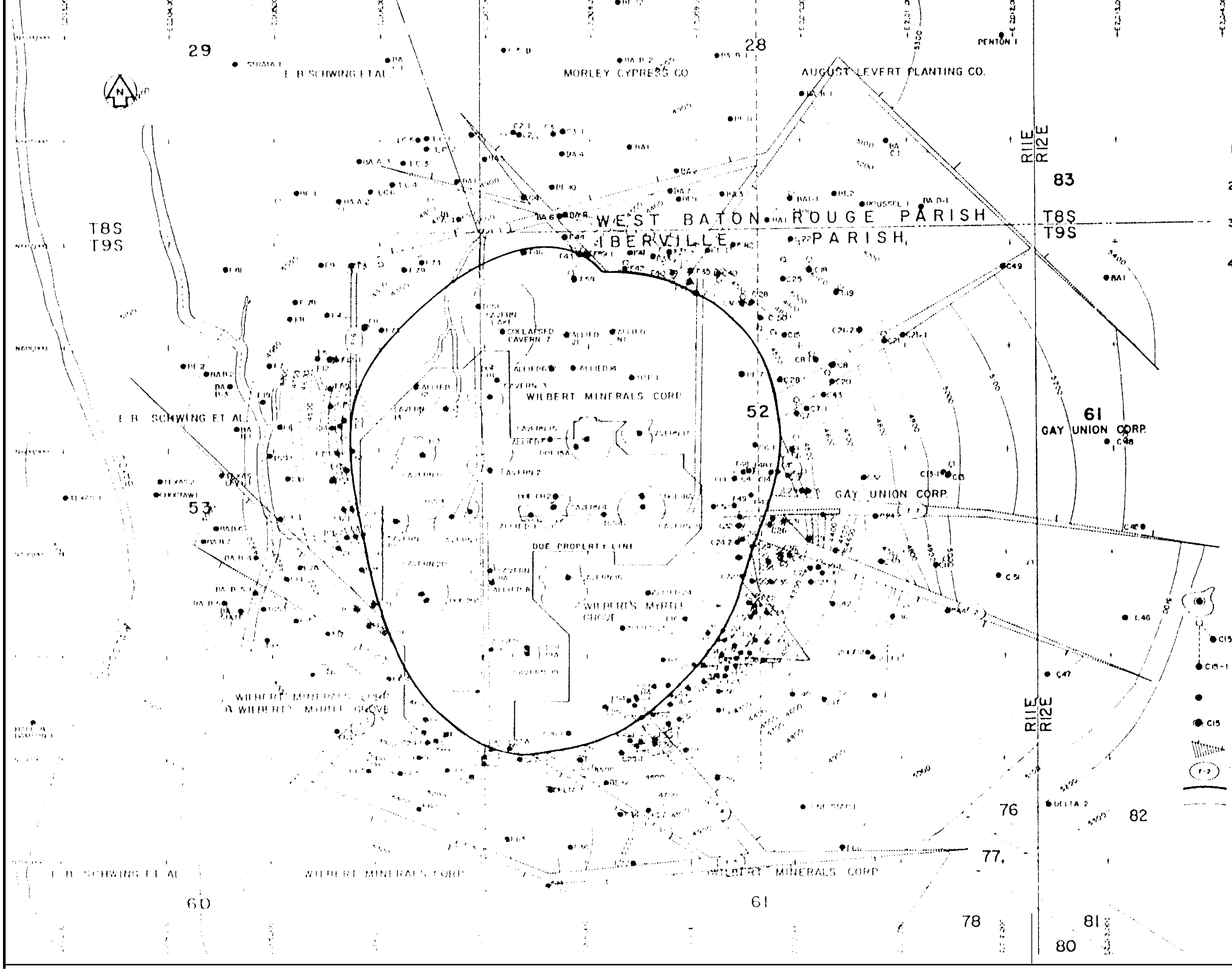
SEPTEMBER 1980
FIG 6.12



NOTES

1. SEE TABLES A-1 THROUGH A-3 FOR EXPLANATION OF WELL NUMBERS
2. SURFACE WELL LOCATIONS ARE ACCURATE TO WITHIN 25 FEET AS MAPPED
3. UNSURVEYED HOLE MAY DEVIATE FROM VERTICAL BY UP TO 2 1/2°
4. CONTOURED DEPTHS MEASURED IN FEET BELOW DRILLING FLOOR

LEGEND

- CAVERN LOCATION SHOWING MAXIMUM CAVERN DIAMETER
- SURFACE LOCATION OF WELL
- C15 SURVEYED BOTTOM HOLE LOCATION OF WELL
- C15-1 SURVEYED BOTTOM HOLE LOCATION OF SIDETRACK HOLE
- DRILLED AS VERTICAL HOLE. NO BOTTOM-HOLE SURVEY AVAILABLE
- C15 LOCATION OF WELL PENETRATING SALT
- STRUCTURAL OFFSET OF FORMATION CAUSED BY FAULT DISPLACEMENT
- F-2 REFERENCED FAULT DISCUSSED IN TEXT
- CONTACT WITH SALT
- DEPTH CONTOURS IN FEET

BAYOU CHOCTAW SPR SITE
STRUCTURE ON TOP OF
NUMBER 4 SAND

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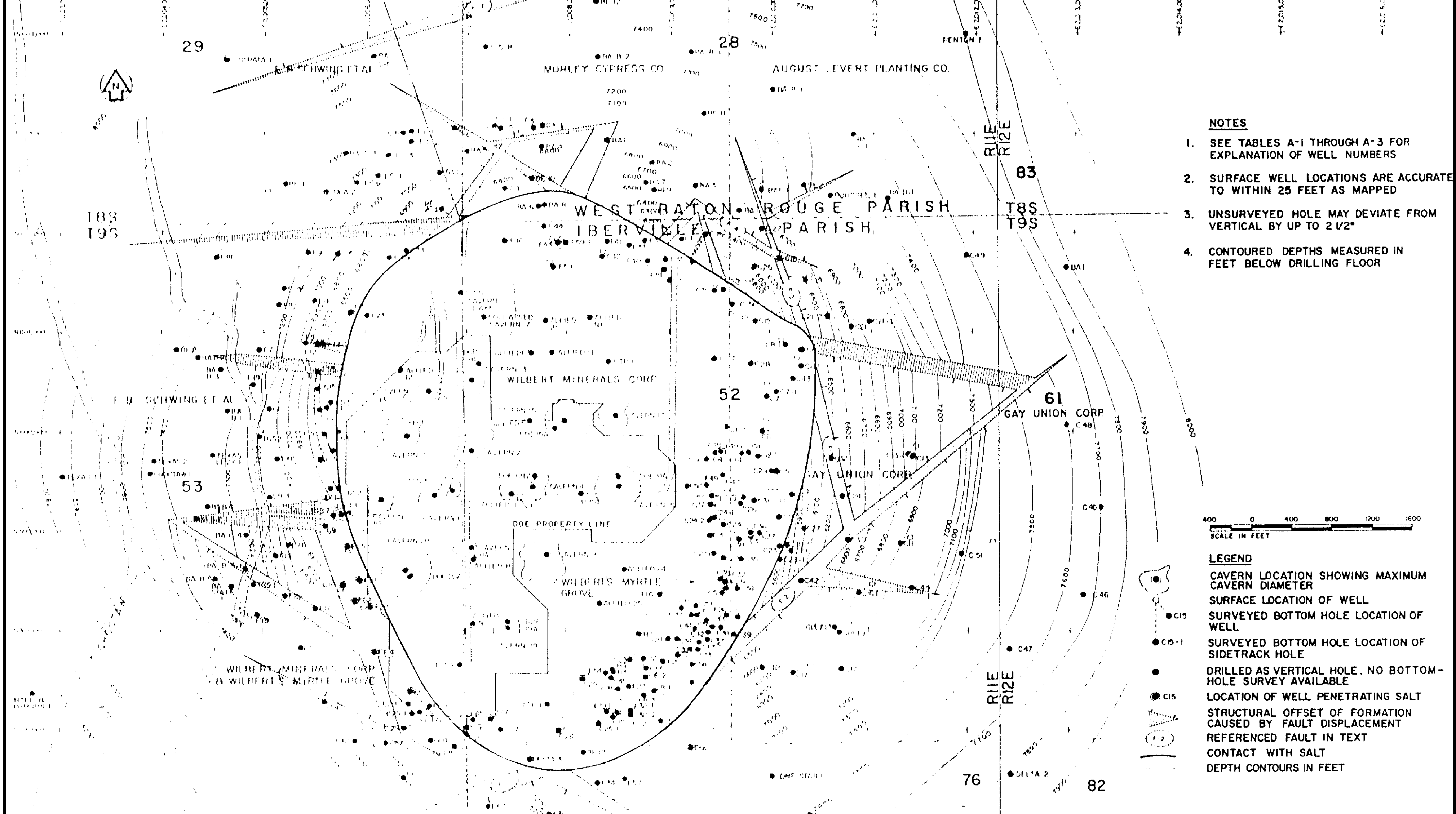
SEPTEMBER 1980

FIG. 6.14



BAYOU CHOCTAW SPR SITE
STRUCTURE ON TOP OF
NUMBER 16 SAND

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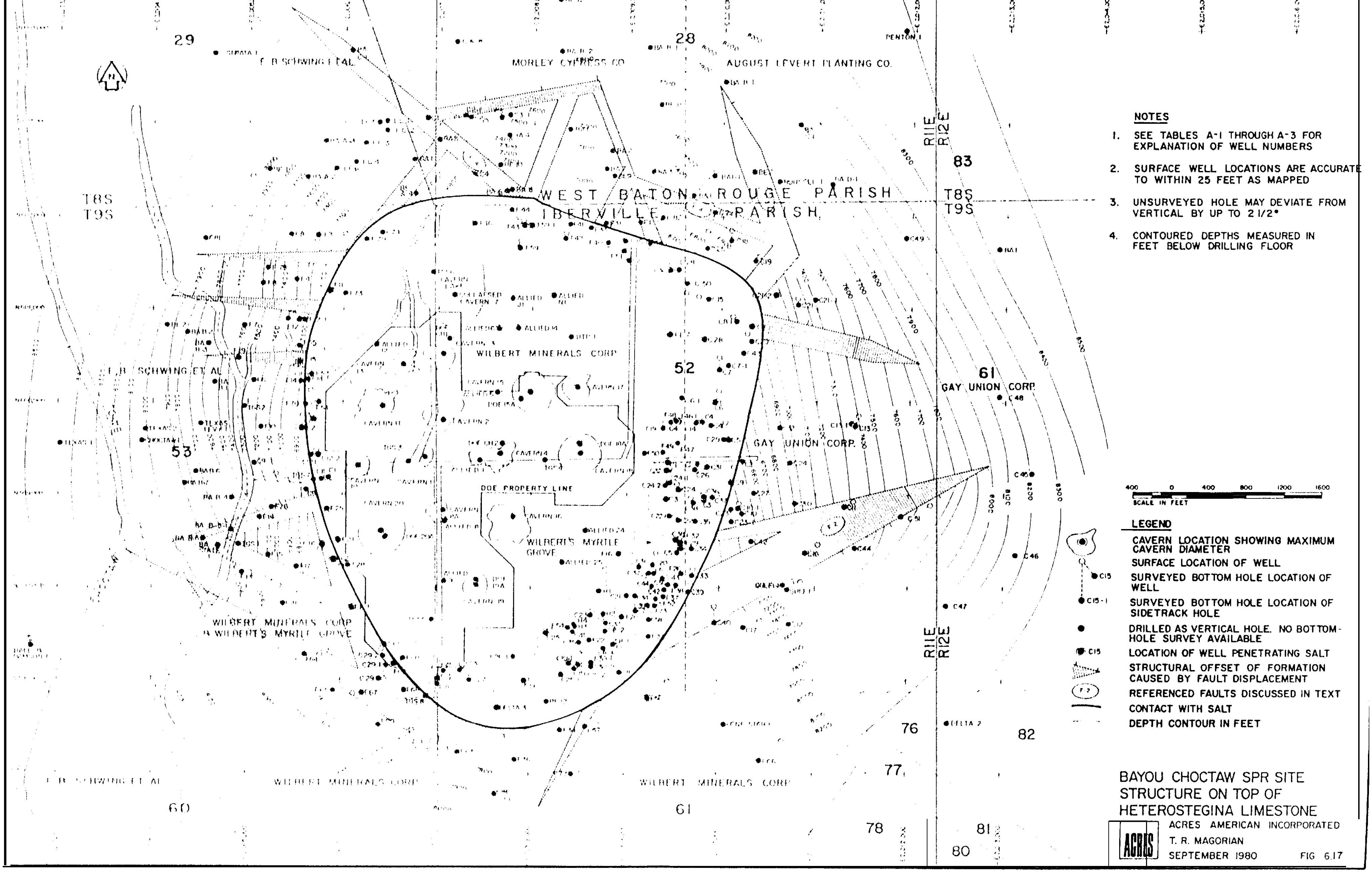
FIG. 6.16



BAYOU CHOCTAW SPR SITE
STRUCTURE ON TOP OF
HETEROSTEGINA LIMESTONE

ACRES AMERICAN INCORPORATED
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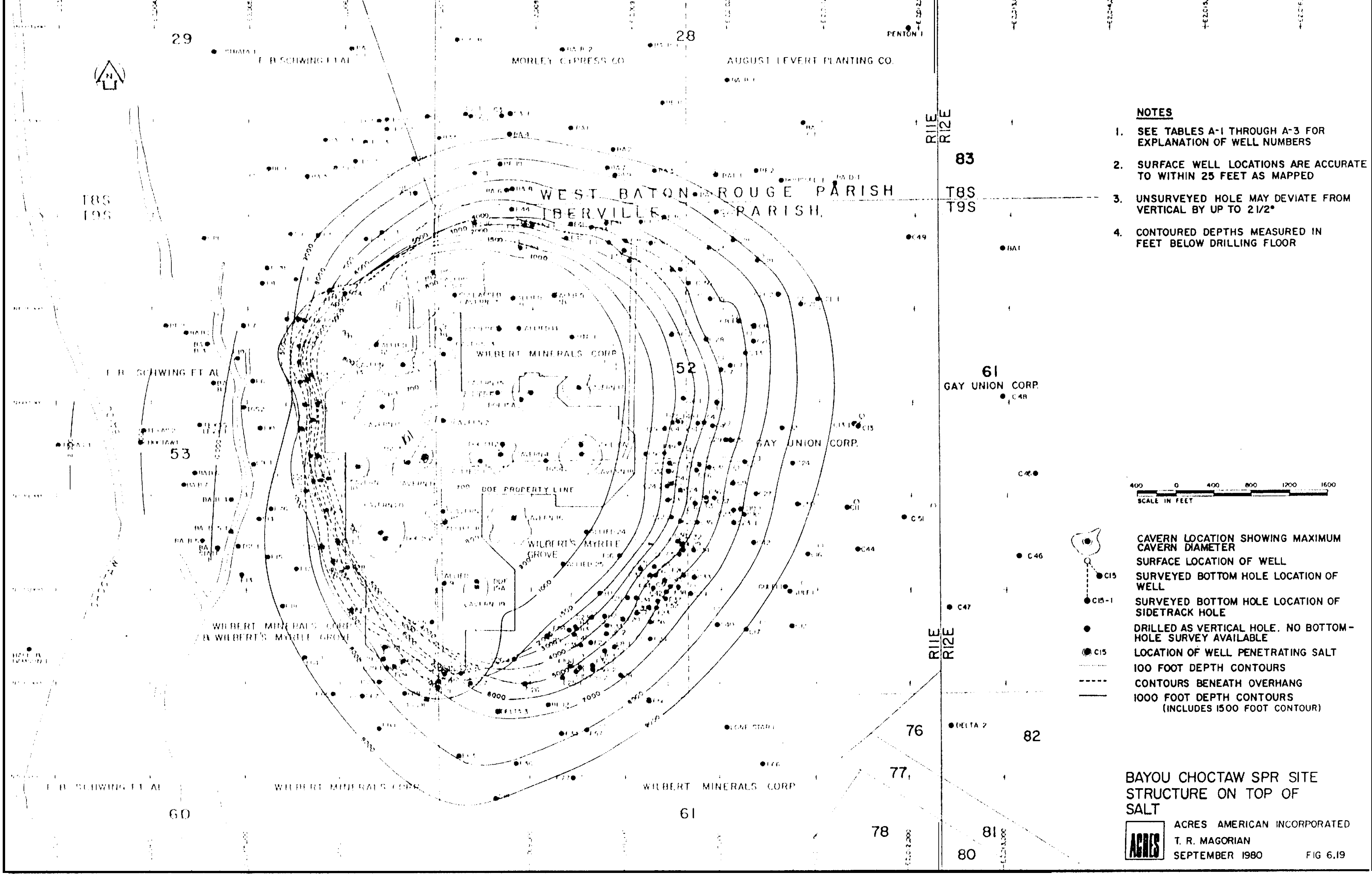
FIG 6.17



BAYOU CHOCTAW SPR SITE
STRUCTURE ON TOP OF SALT

ACRES AMERICAN INCORPORATED
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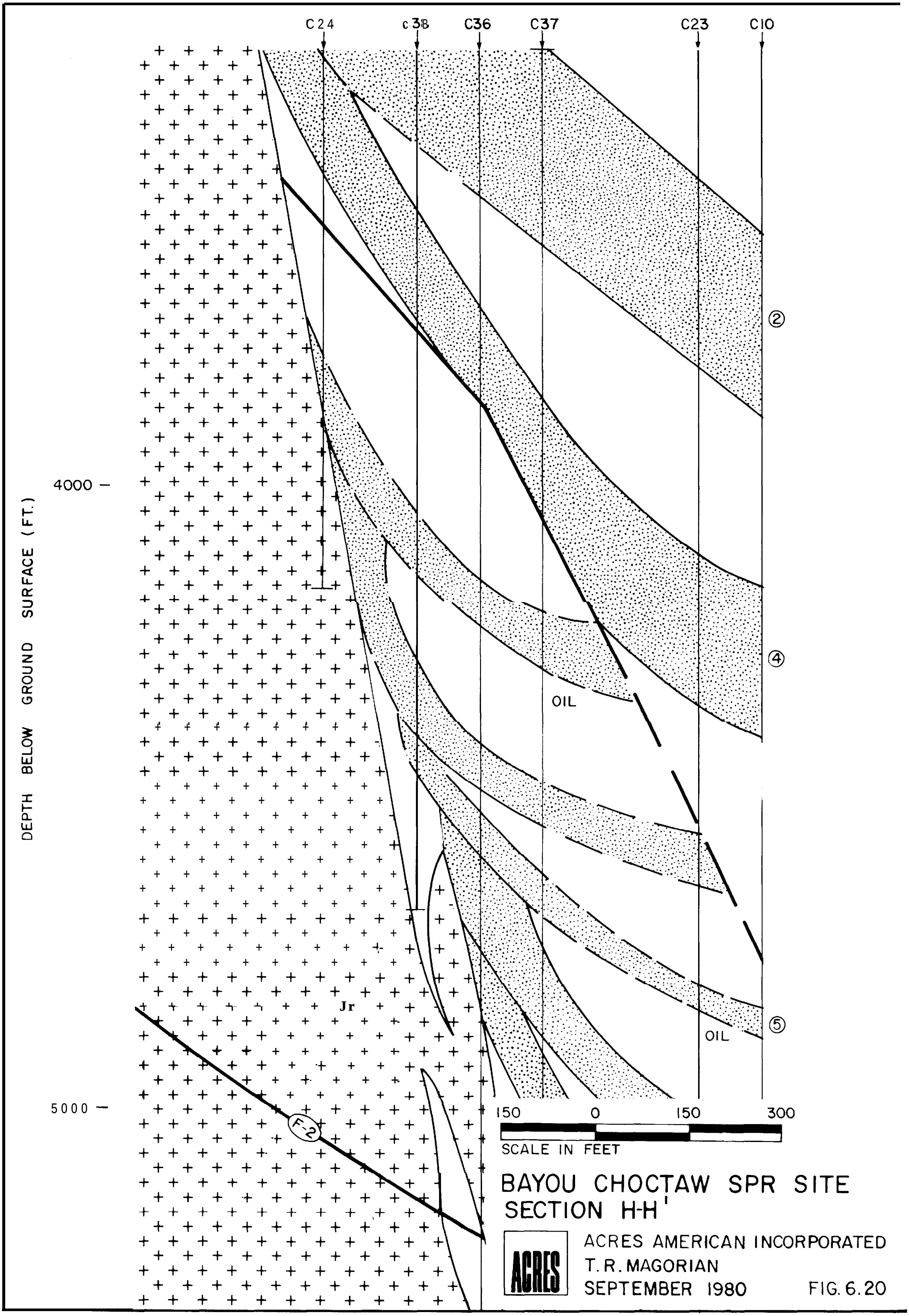
FIG 6.19



BAYOU CHOCTAW SPR SITE
SECTION H-H'

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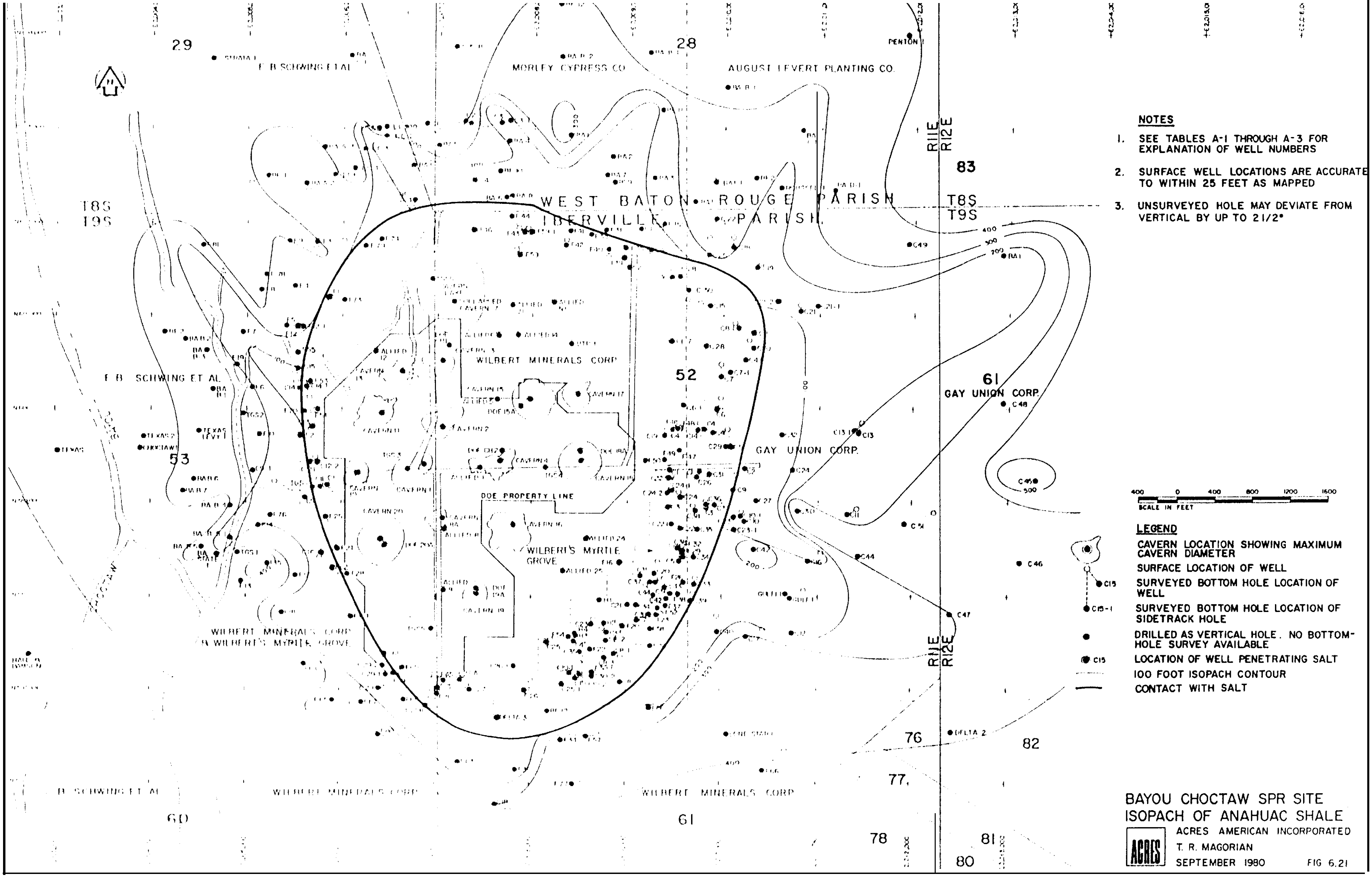
FIG. 6.20



BAYOU CHOCTAW SPR SITE
ISOPACH OF ANAHUAC SHALE
ACRES AMERICAN INCORPORATED
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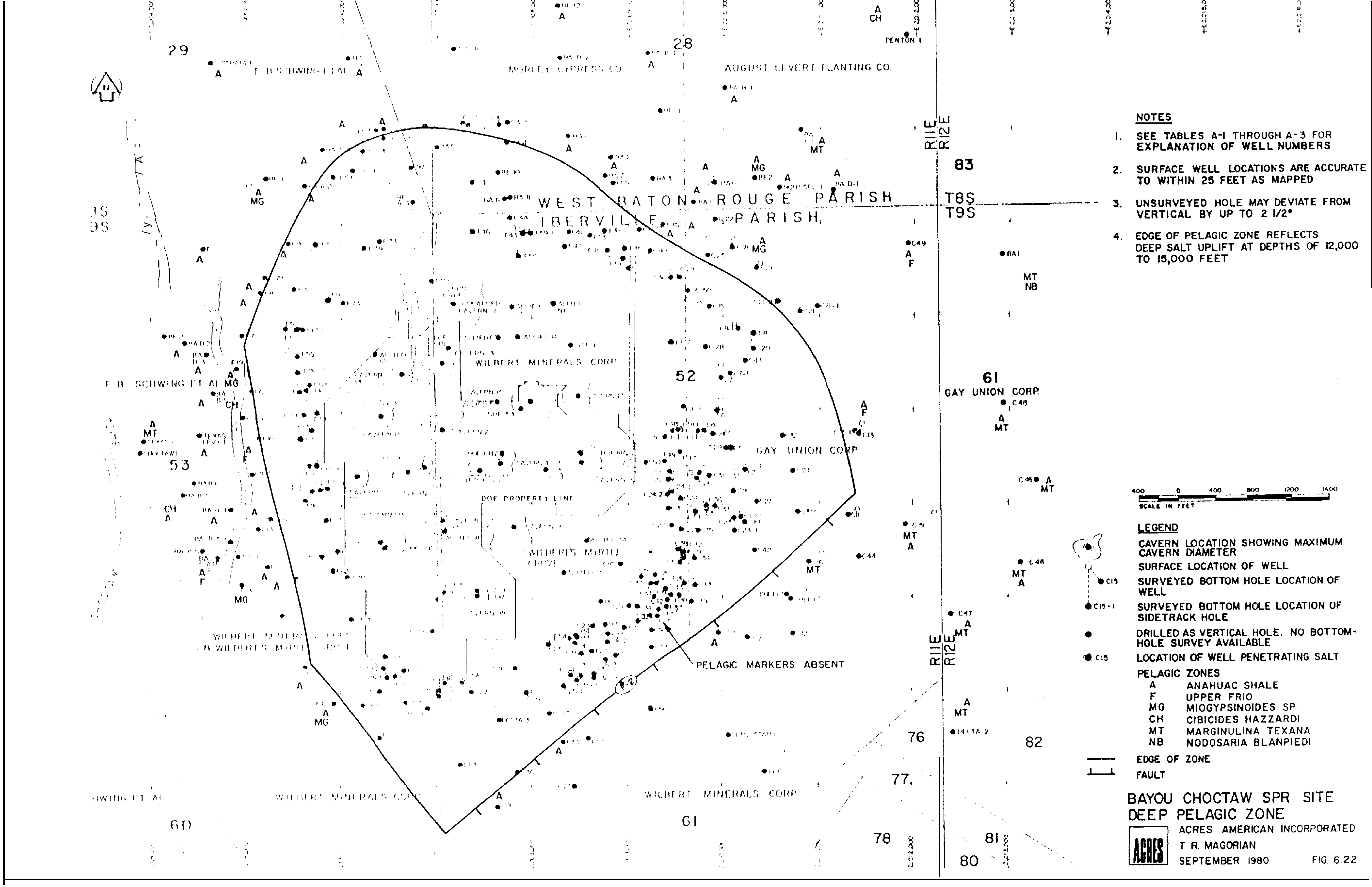
FIG 6.21



BAYOU CHOCTAW SPR SITE
DEEP PELAGIC ZONE

ACRES AMERICAN INCORPORATED
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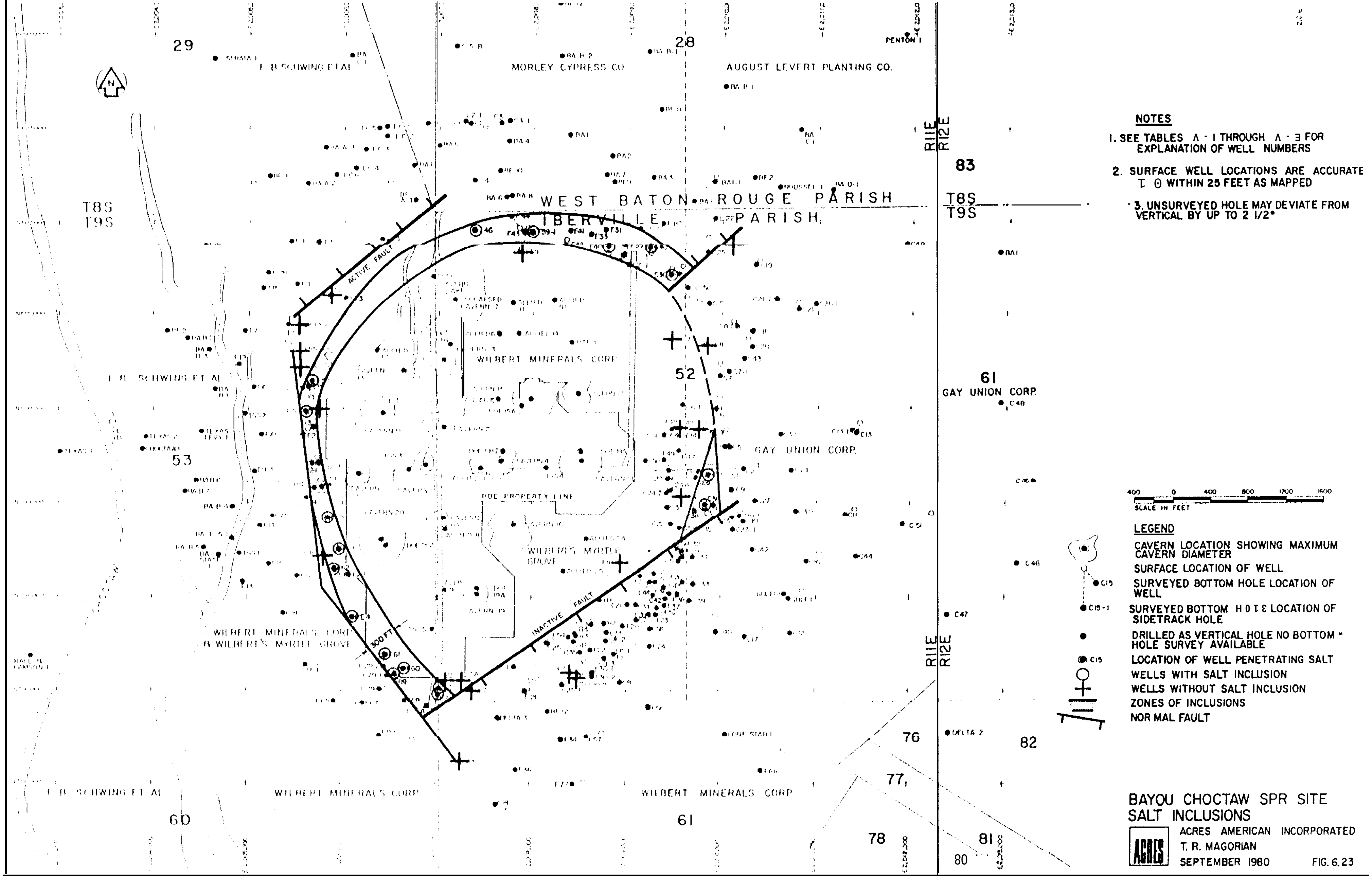
SEPTEMBER 1980

FIG. 6.22



29
28
E. B. SCHWING ET AL
MORLEY CYPRESS CO
AUGUST LEVERT PLANTING CO.
PENTON 1
T8S
T9S
WEST BATON ROUGE PARISH
IBERVILLE PARISH
ACTIVE FAULT
INACTIVE FAULT
300 FT
WILBERT MINERALS CORP
52
53
E. B. SCHWING ET AL
61
GAY UNION CORP
GAY UNION CORP.
DOE PROPERTY LINE
WILBERT'S MYRTLE GROVE
WILBERT MINERALS CORP
& WILBERT'S MYRTLE GROVE
R11E
R12E
83
T8S
T9S
76
77
78
80
81
82
E. B. SCHWING ET AL
WILBERT MINERALS CORP
WILBERT MINERALS CORP
60
61
NOTES
1. SEE TABLES A - 1 THROUGH A - 3 FOR EXPLANATION OF WELL NUMBERS
2. SURFACE WELL LOCATIONS ARE ACCURATE TO WITHIN 25 FEET AS MAPPED
3. UNSURVEYED HOLE MAY DEVIATE FROM VERTICAL BY UP TO 2 1/2°
400 0 400 800 1200 1600
SCALE IN FEET
LEGEND
CAVERN LOCATION SHOWING MAXIMUM CAVERN DIAMETER
SURFACE LOCATION OF WELL
SURVEYED BOTTOM HOLE LOCATION OF WELL
SURVEYED BOTTOM HOLE LOCATION OF SIDETRACK HOLE
DRILLED AS VERTICAL HOLE NO BOTTOM - HOLE SURVEY AVAILABLE
LOCATION OF WELL PENETRATING SALT
WELLS WITH SALT INCLUSION
WELLS WITHOUT SALT INCLUSION
ZONES OF INCLUSIONS
NORMAL FAULT
BAYOU CHOCTAW SPR SITE
SALT INCLUSIONS
ACRES AMERICAN INCORPORATED
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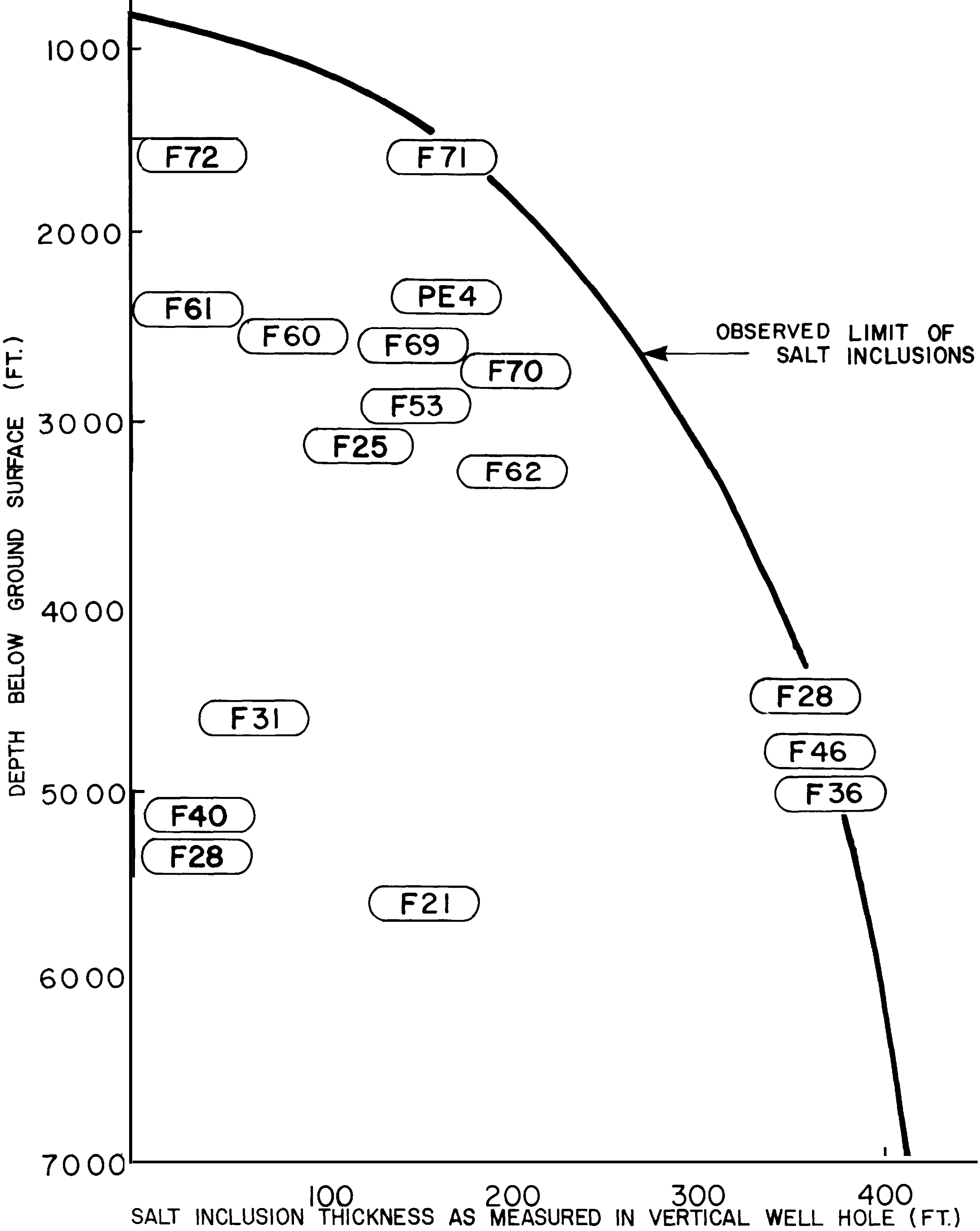
SEPTEMBER 1980
FIG. 6.23



NOTE: F61 WELL IDENTIFICATION
SEE FIGURE 2.2
FOR LOCATION

BAYOU CHOCTAW SPR SITE
SALT INCLUSIONS BY DEPTH

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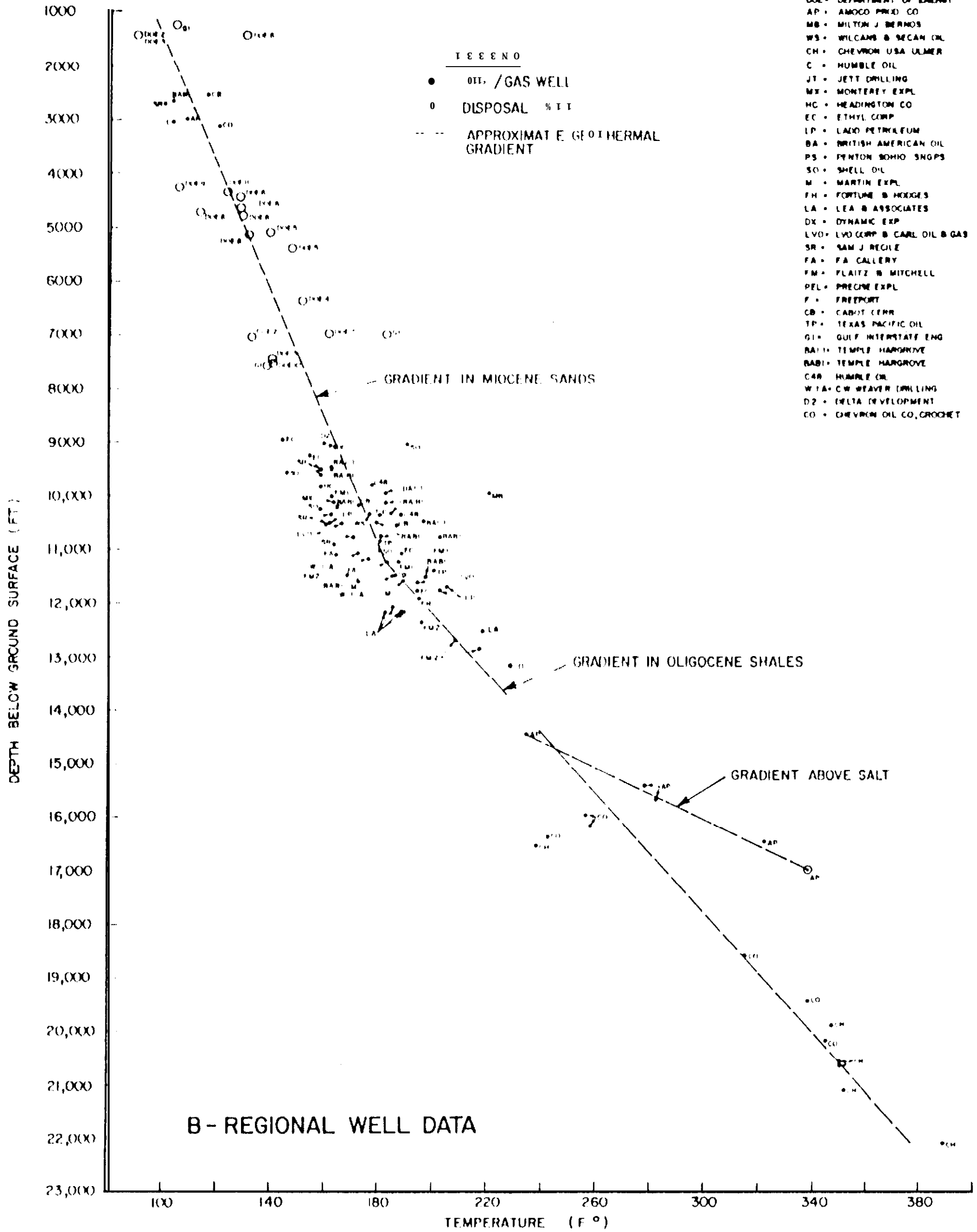
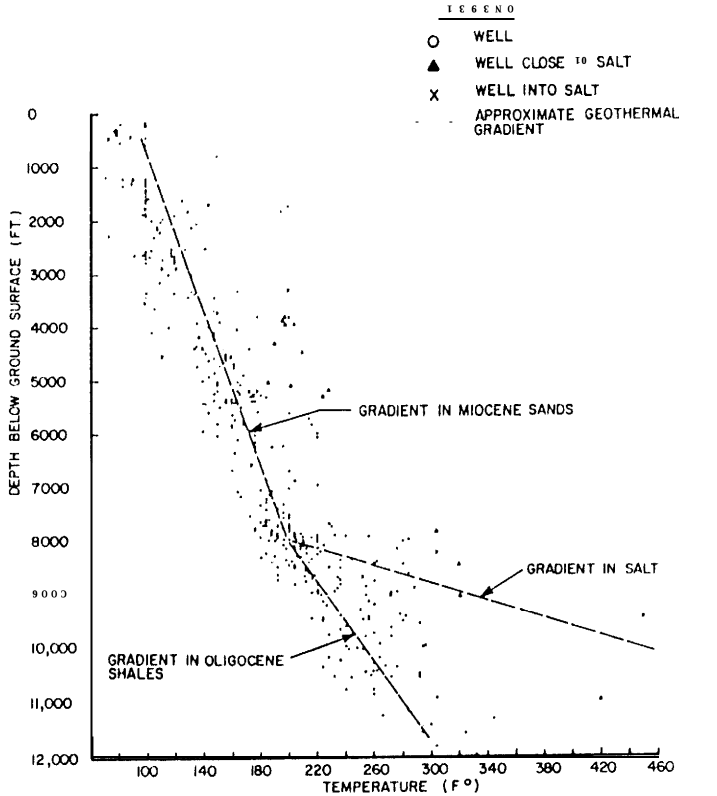
FIG. 6.24





A- BAYOU CHOCTAW SITE DATA

NOTE REFER TO FIG. 2.2 FOR WELL LOCATIONS

BAYOU CHOCTAW SPR SITE
TEMPERATURE – DEPTH PLOTS

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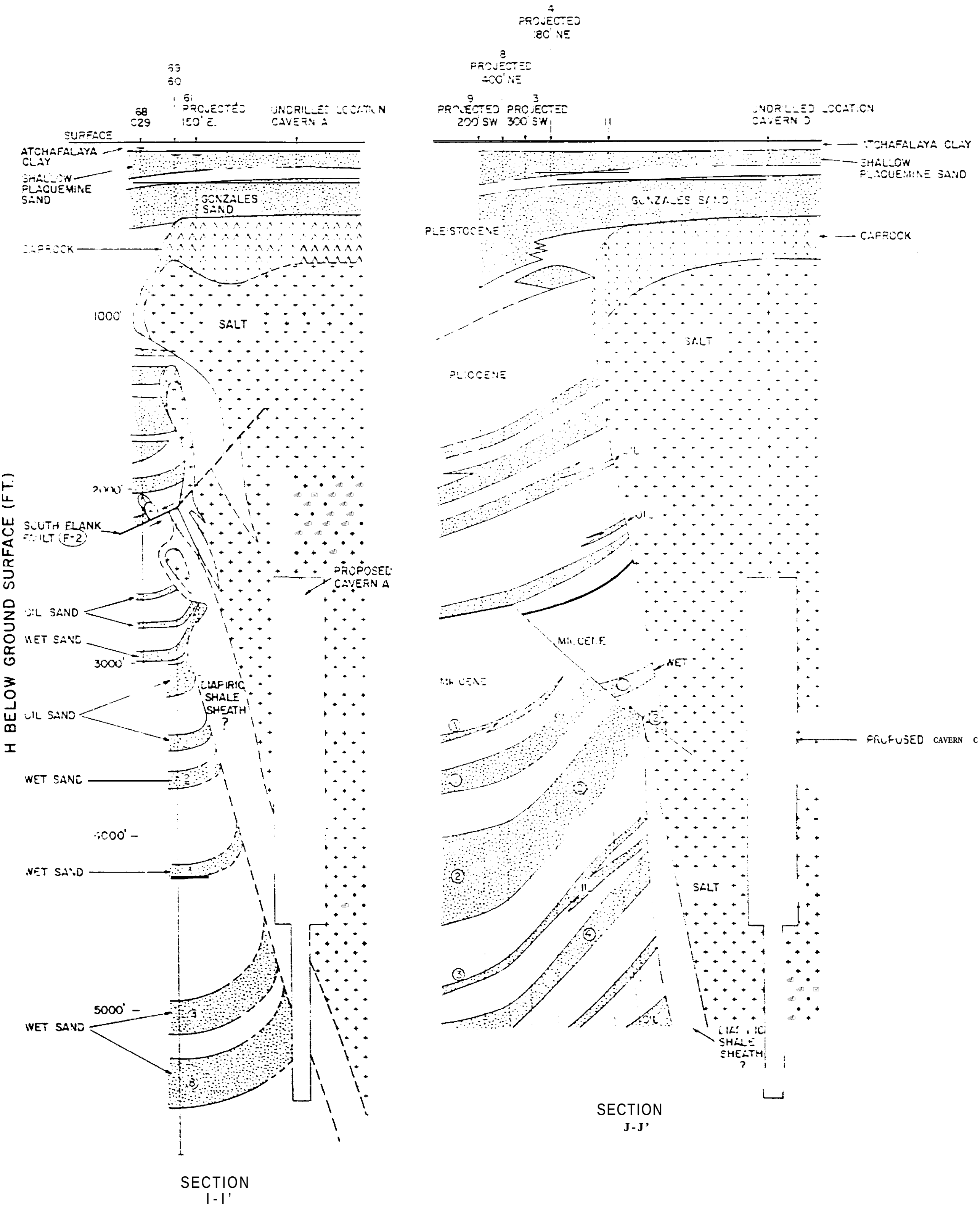
SEPTEMBER 1980 FIG. 6.25



NOTES

1. UNSURVEYED HOLES MAY DEVIATE FROM VERTICAL UP TO 2 1/2°.
2. REFER TO TABLE 4.1 FOR LEGEND.
3. REFER TO FIGURE 6.1 FOR SECTION LOCATIONS.

BAYOU CHOCTAW SPR SITE
SECTIONS I-I' & J-J'

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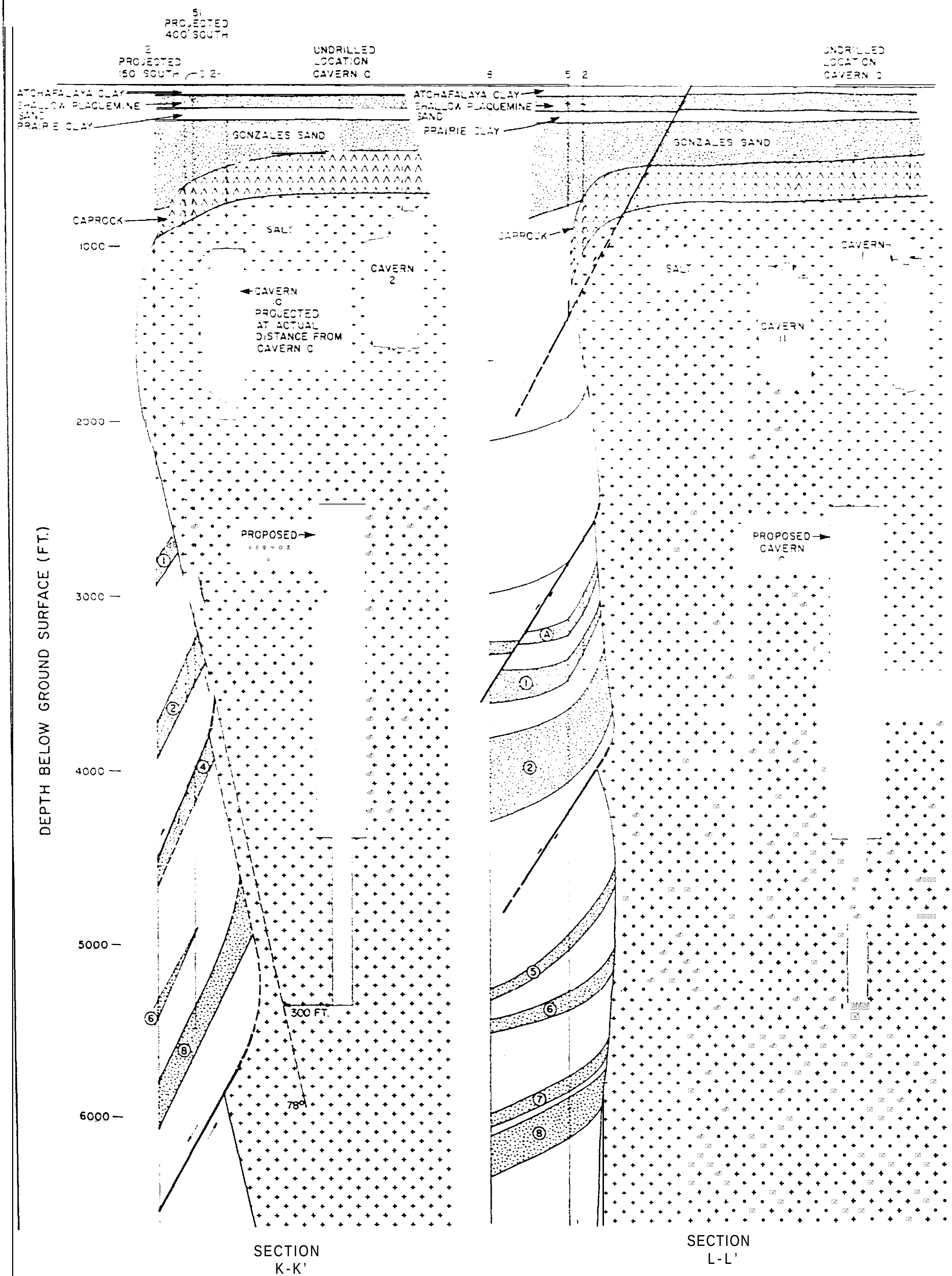
F...C.26



NOTES

1. UNSURVEYED HOLES MAY DEVIATE FROM VERTICAL UP TO 2 1/2 °.
2. REFER TO TABLE 4.1 FOR LEGEND.
3. REFER TO FIGURE 6. FOR SECTION LOCATIONS.

BAYOU CHOCTAW SPR SITE
SECTIONS K-K' & L-L'

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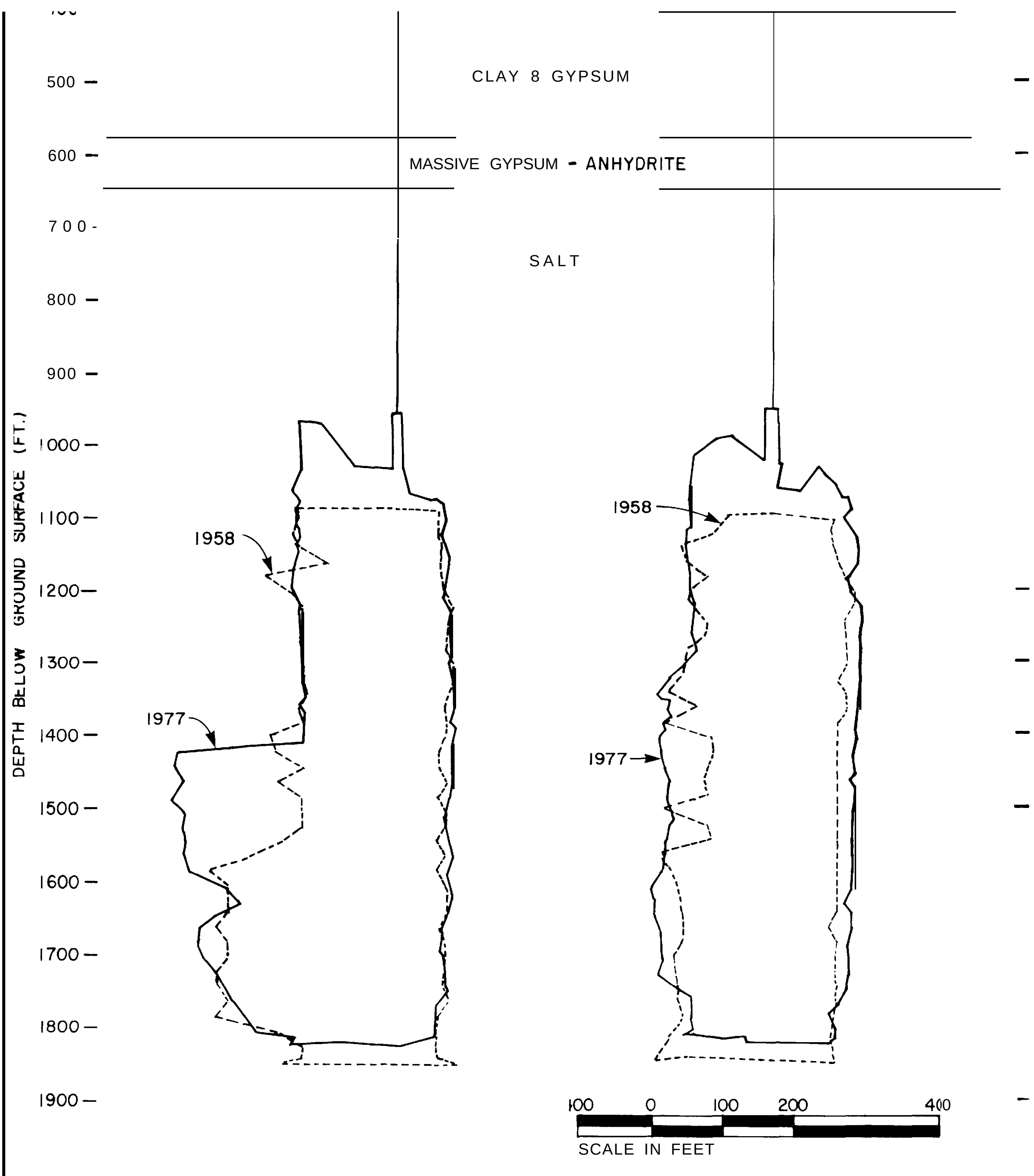
FIG. 6.27



NOTE : DATES REFER TO SONAR SURVEYS
DATE DRILLED : NOVEMBER 22, 1937 TO DECEMBER 21, 1937
ELEVATION (MEAN GULF LEVEL) : + 7.0 FEET
TOP OF CAPROCK : 407 FEET
TOP OF SALT: 579 FEET
ORIGINAL TOTAL DEPTH : 1988 FEET
PRESENT CAVERN TOP (1977) : 950 FEET
PRESENT CAVERN BASE (1977) : 1810 FEET
PRESENT CAVERN VOLUME (1977) : 8.42 MM BARRELS
REFERENCE : PB-KBB. 1978b 8 19783

BAYOU CHOCTAW SPR SITE
PROFILES OF CAVERN I

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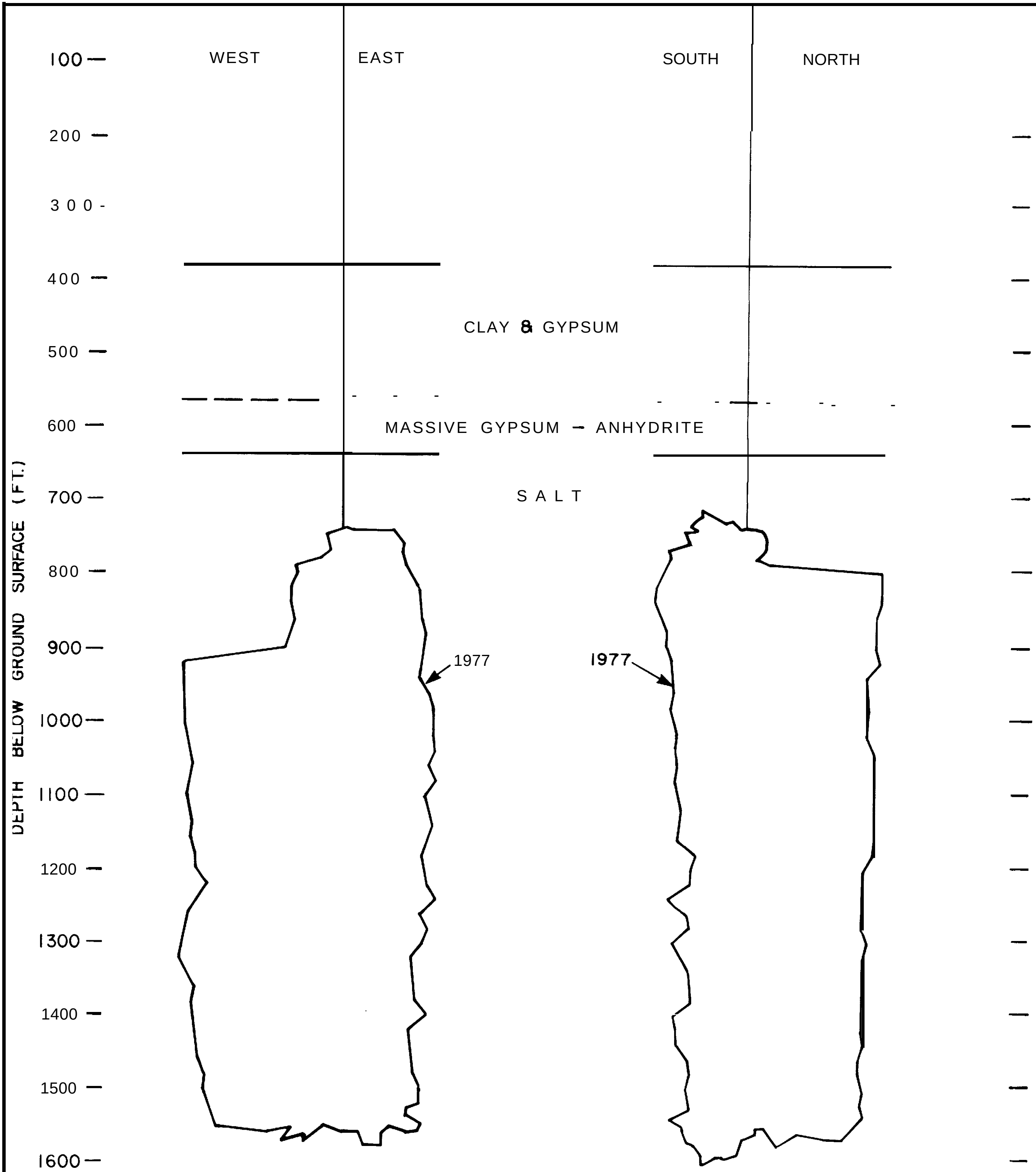
FIG. 6.28



NOTE: DATES REFER TO SONAR SURVEYS
DATE DRILLED: 1934
ELEVATION (MEAN GULF LEVEL): + 7.0 FEET
TOP OF CAPROCK : 376 FEET
TOP OF SALT : 639 FEET
ORIGINAL TOTAL DEPTH : 1846 FEET
PRESENT CAVERN TOP (1977) : 715 FEET
PRESENT CAVERN BASE (1977): 1590 FEET
PRESENT CAVERN VOLUME (1977) : 9.02 MM BARRELS

REFERENCE : PB- KBB, 1978b & 1978i

100 0 100 200 400
SCALE IN FEET

BAYOU CHOCTAW SPR SITE
PROFILES OF CAVERN 2

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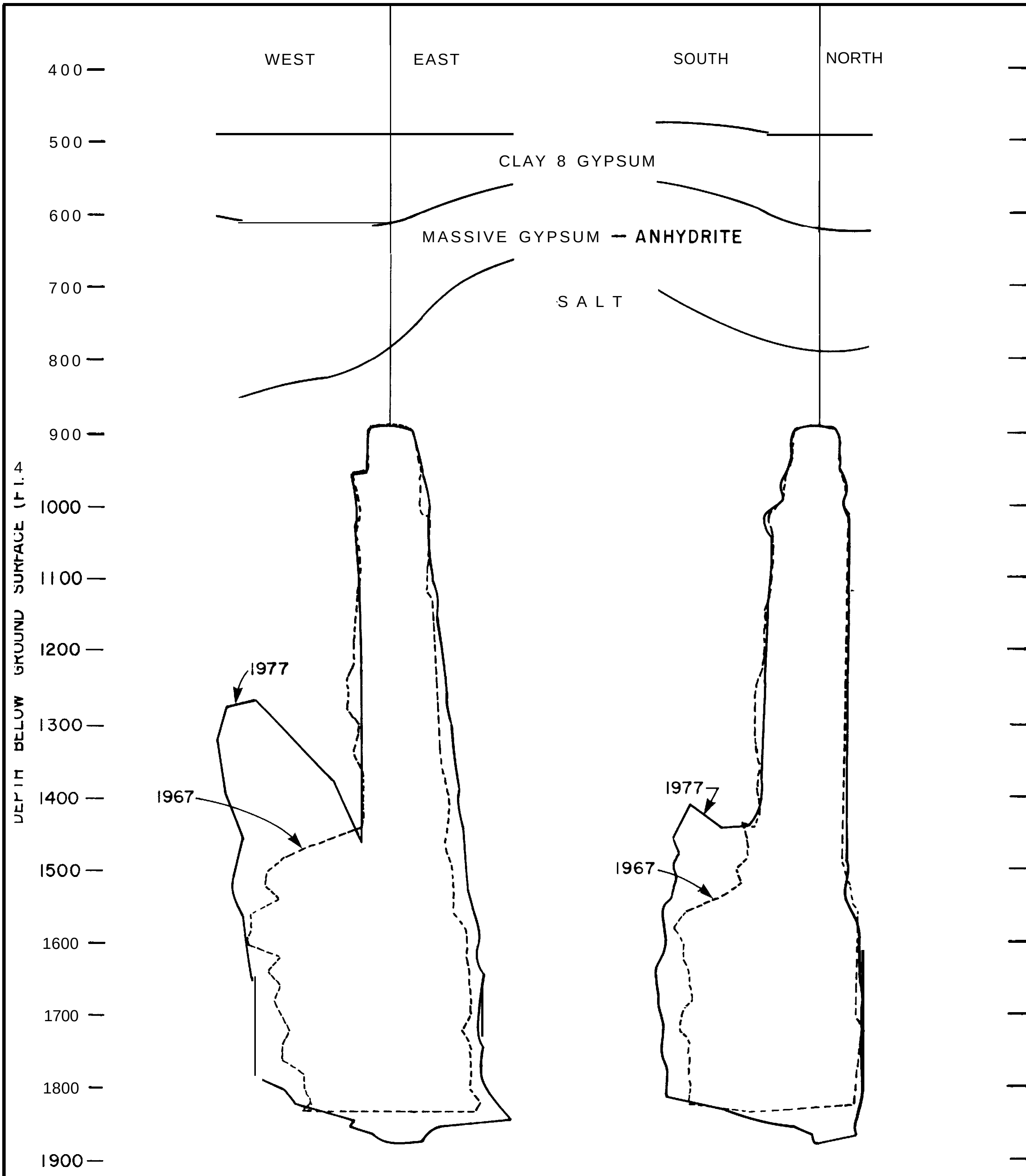
SEPTEMBER 1980

FIG. 6.29



NOTE: DATES REFER TO SONAR SURVEYS
DATE DRILLED: 1934
ELEVATION (MEAN GULF LEVEL) : + 5.7 FEET
TOP OF CAPROCK : 506 FEET
TOP OF SALT : 79 I FEET
ORIGINAL TOTAL DEPTH : 2000 FEET
PRESENT CAVERN TOP (1977) : 890 FEET
PRESENT CAVERN BASE (1977) : 1875 FEET
PRESENT CAVERN VOLUME (1977) : 5.01 MM BARRELS

REFERENCE : PB- KBB, 1978 b 8 1978i

100 0 100 200 400
SCALE IN FEET

BAYOU CHOCTAW SPR SITE
PROFILES OF CAVERN 3

ACRES
ACRES AMERICAN INCORPORATED
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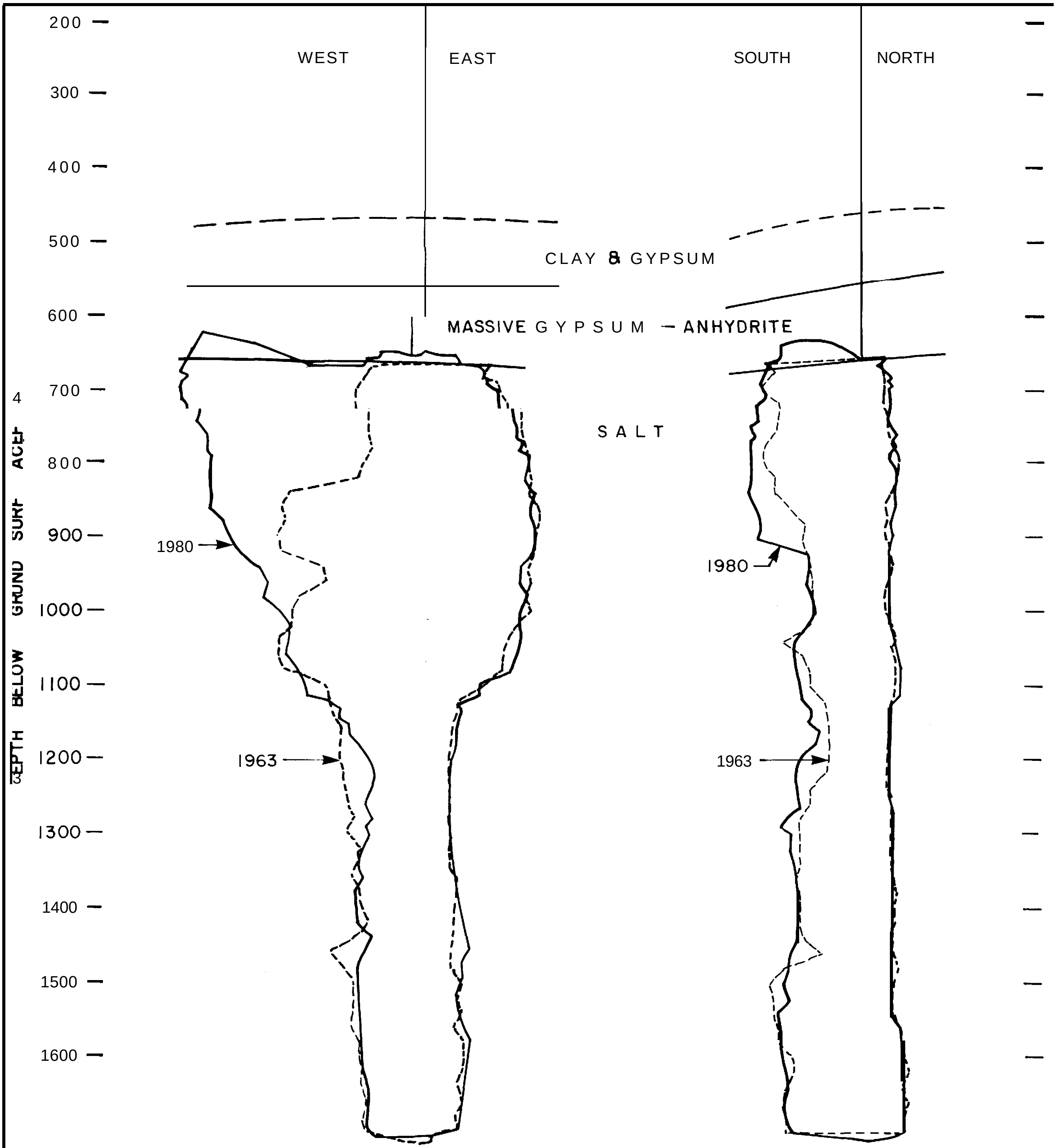
SEPTEMBER 1980

FIG. 6.30



NOTE: DATES REFER TO SONAR SURVEYS
DATE DRILLED: 1935
ELEVATION (MEAN GULF LEVEL): + 7.4 FEET
TOP OF CAPROCK : 551 FEET
TOP OF SALT : 662 FEET
ORIGINAL TOTAL DEPTH : 1990 FEET
PRESENT CAVERN TOP (1980) : 620 FEET
PRESENT CAVERN BASE (1980) : 1710 FEET
PRESENT CAVERN VOLUME (1980) : 5.94 MM BARRELS

REFERENCE : PB- KBB, 1978b, 1978 i,& DOWELL,1980b

100 0 100 200 40

SCALE IN FEET

BAYOU CHOCTAW SPR SITE
PROFILES OF CAVERN 4

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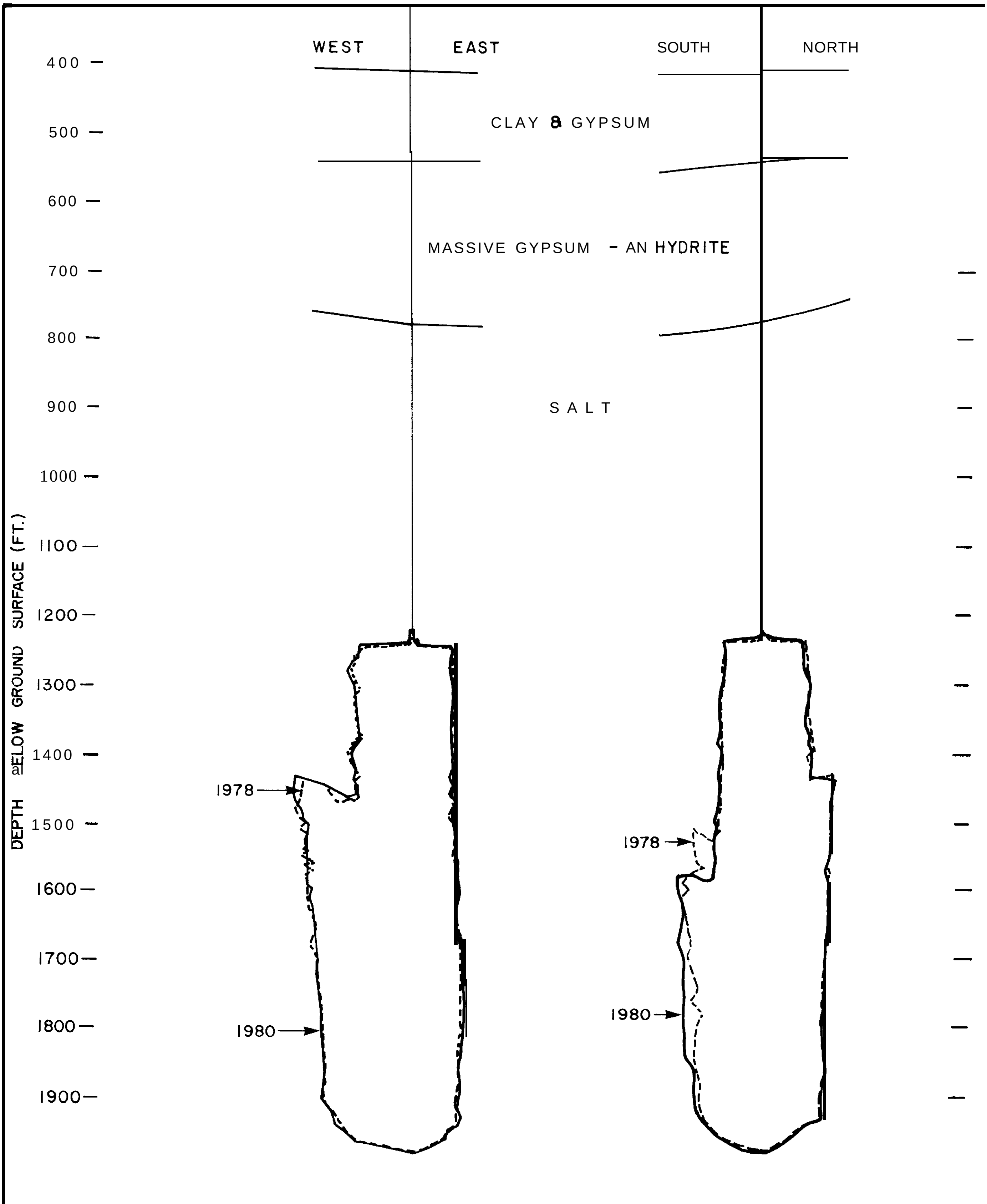
SEPTEMBER 1980

FIG. 6.31



NOTE: DATES REFER TO SONAR SURVEYS
DATE DRILLED: 1944
ELEVATION (MEAN GULF LEVEL): + 7.0 FEET
TOP OF CAPROCK : 437 FEET
TOP OF SALT : 776 FEET
ORIGINAL TOTAL DEPTH : 2007 FEET
PRESENT CAVERN TOP (1980) : 1235 FEET
PRESENT CAVERN BASE (1980) : 1976 FEET
PRESENT CAVERN VOLUME (1980) : 3.12 MM BARRELS

REFERENCE : PB- KBB, 1978 b, 1978 i, & DOWELL, 1980a

100 0 100 200 400
SCALE IN FEET

BAYOU CHOCTAW SPR SITE
PROFILES OF CAVERN 8A

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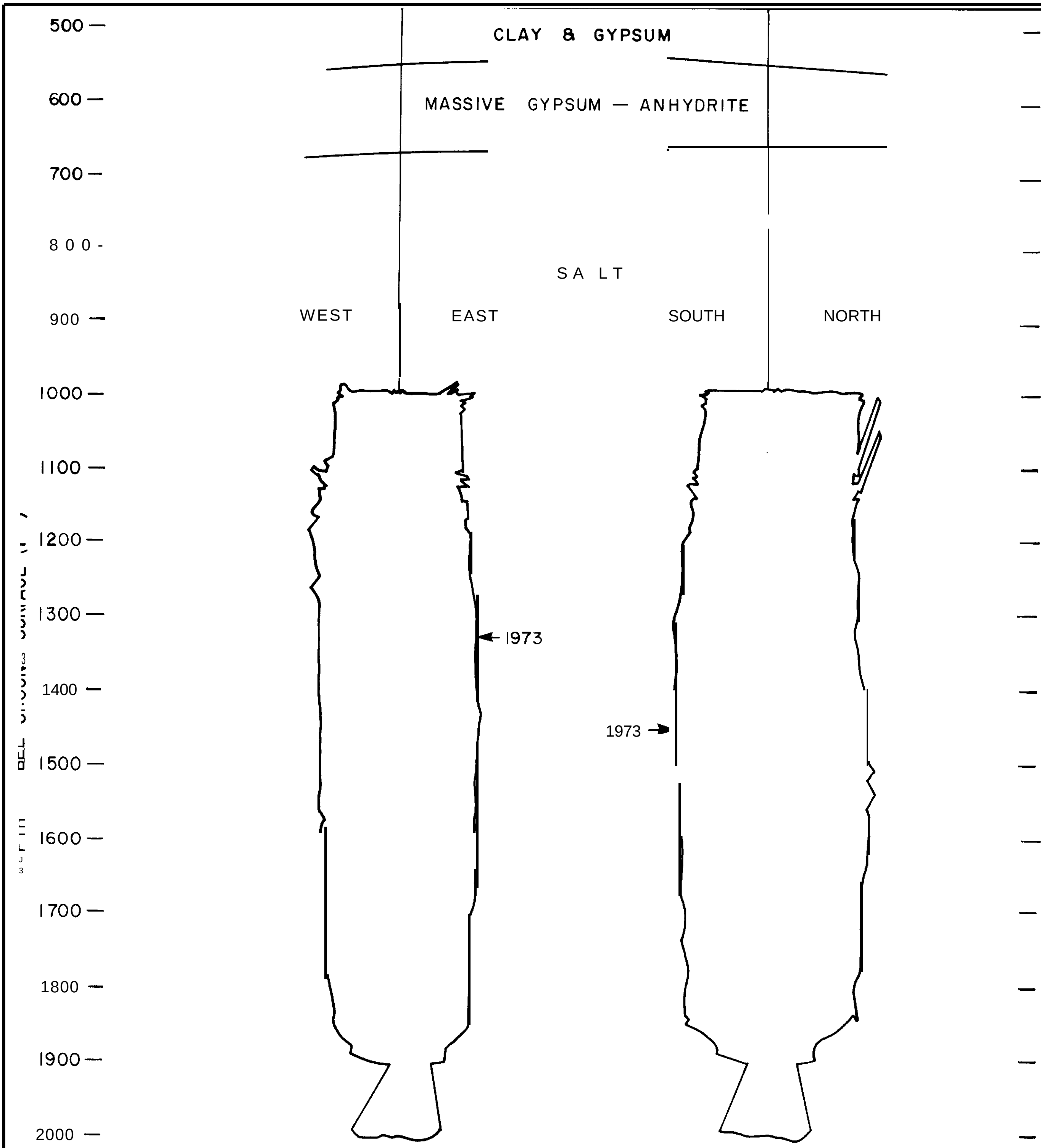
SEPTEMBER 1980

FIG. 6.32



NOTE: DATES REFER TO SONAR SURVEYS
DATE DRILLED: 1947
ELEVATION (MEAN GULF LEVEL): + 9.75 FEET
TOP OF CAPROCK : 549 FEET
TOP OF SALT : 661 FEET
ORIGINAL TOTAL DEPTH : 1942 FEET
PRESENT CAVERN TOP (1973) : 990 FEET
PRESENT CAVERN BASE (1973): 1902 FEET
PRESENT CAVERN VOLUME (1973) : 6.4 MM BARRELS

REFERENCE : PB-KBB, 1978b & 1978i

100 0 100 200 400

SCALE IN FEET

BAYOU CHOCTAW SPR SITE
PROFILES OF CAVERN 10

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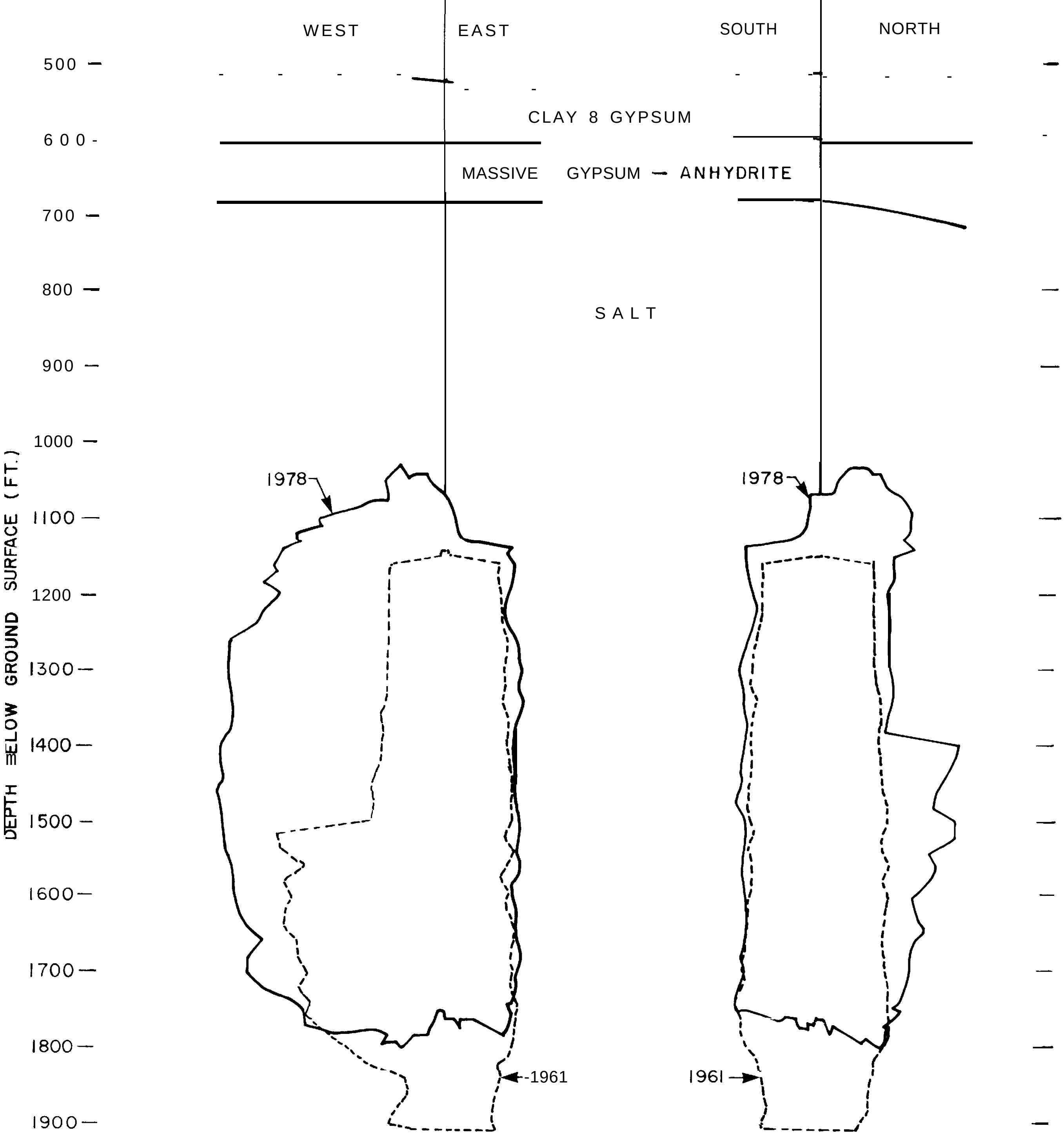
SEPTEMBER 1980

FIG. 6.33



NOTE: DATES REFER TO SONAR SURVEYS
DATE DRILLED: 1947
ELEVATION (MEAN GULF LEVEL) : + 7.0 FEET
TOP OF CAPROCK : 605 FEET
TOP OF SALT : 683 FEET
ORIGINAL TOTAL DEPTH : 1928 FEET
PRESENT CAVERN TOP (1980) : 1030 FEET
PRESENT CAVERN BASE (1980) : 1800 FEET
PRESENT CAVERN VOLUME (1978): 9.5 MM BARRELS

REFERENCE : PB – KBB, 1978 b & 1978 i

100 0 100 200 400
SCALE IN FEET

BAYOU CHOCTAW SPR SITE
PROFILES OF CAVERN 11

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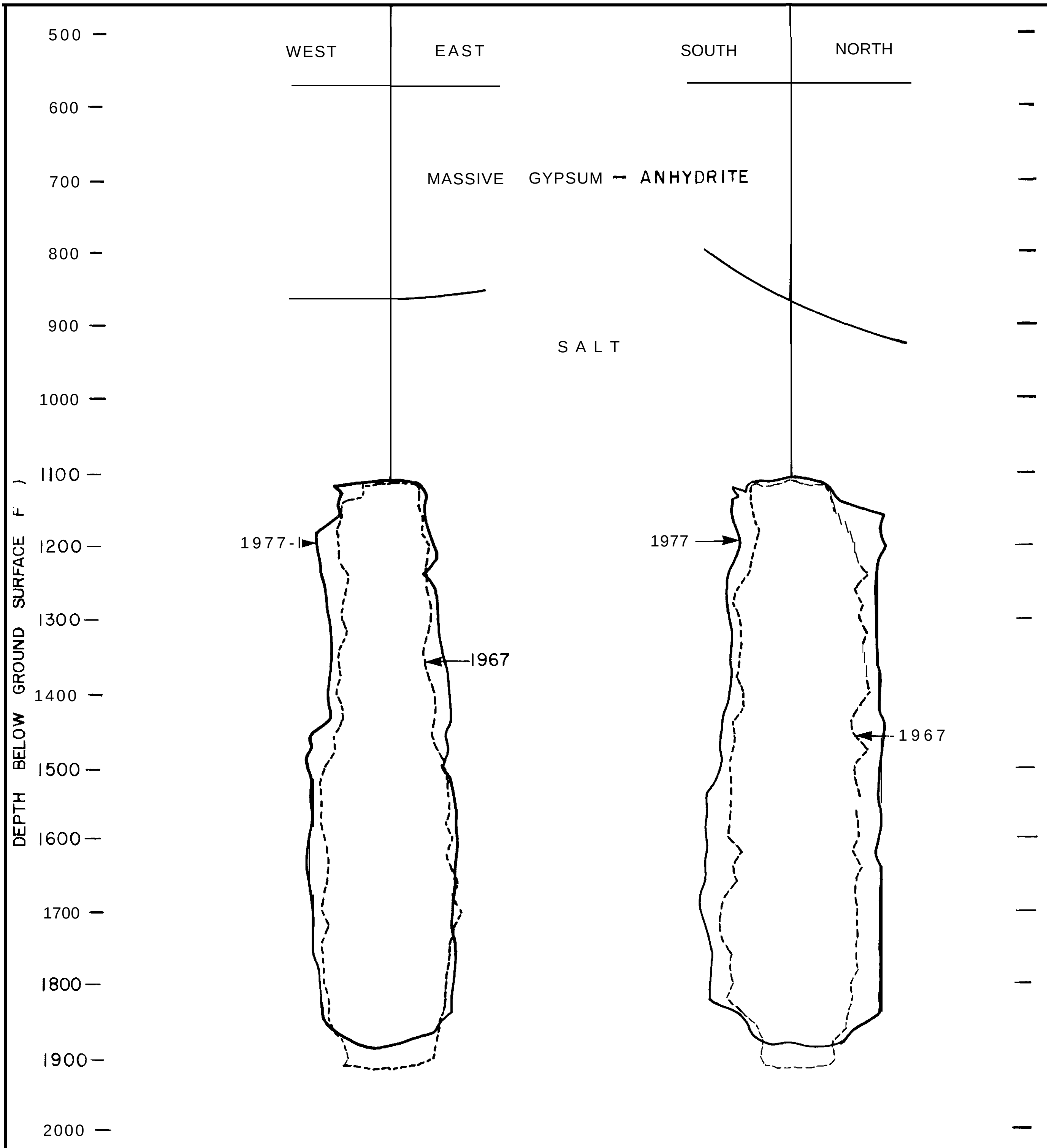
SEPTEMBER 1980 FIG. 6.34



NOTE: DATES REFER TO SONAR SURVEYS
DATE DRILLED: 1948
ELEVATION (MEAN GULF LEVEL) : + 8.6 FEET
TOP OF CAPROCK : 571 FEET
TOP OF SALT : 875 FEET
ORIGINAL TOTAL DEPTH : 1915 FEET
PRESENT CAVERN TOP (1977) : 1103 FEET
PRESENT CAVERN BASE (1977) : 1880 FEET
PRESENT CAVERN VOLUME (1977) : 4.31 MM BARRELS

REFERENCE : PB-KBB, 1978b & 1978 i

100 0 100 200 400
SCALE IN FEET

BAYOU CHOCTAW SPR SITE
PROFILES OF CAVERN 13

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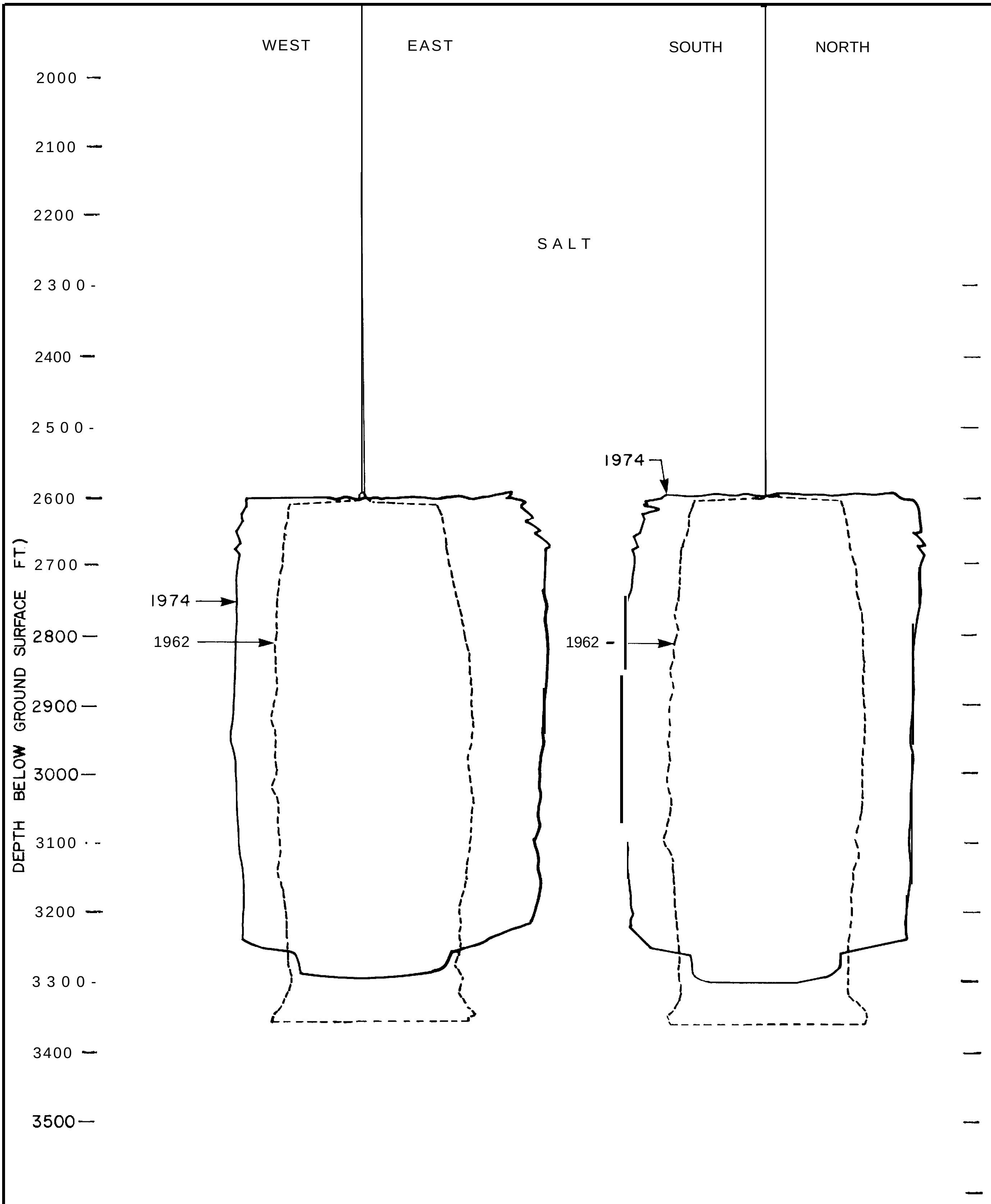
SEPTEMBER 1980

FIG. 6.35



NOTE : DATES REFER TO SONAR SURVEYS
DATE DRILLED: 1953
ELEVATION (MEAN GULF LEVEL) : + 9.0 FEET
TOP OF CAPROCK : 469 FEET
TOP OF SALT: 637 FEET
ORIGINAL TOTAL DEPTH : 3357 FEET
PRESENT CAVERN TOP (1974): 2597 FEET
PRESENT CAVERN BASE (1974) : 3297 FEET
PRESENT CAVERN VOLUME (1974) : 16.62 MM BARRELS

REFERENCE : PB -KBB, 1978 b & 1978i

100 0 100 200 400
SCALE IN FEET

BAYOU CHOCTAW SPR SITE
PROFILES OF CAVERN 15

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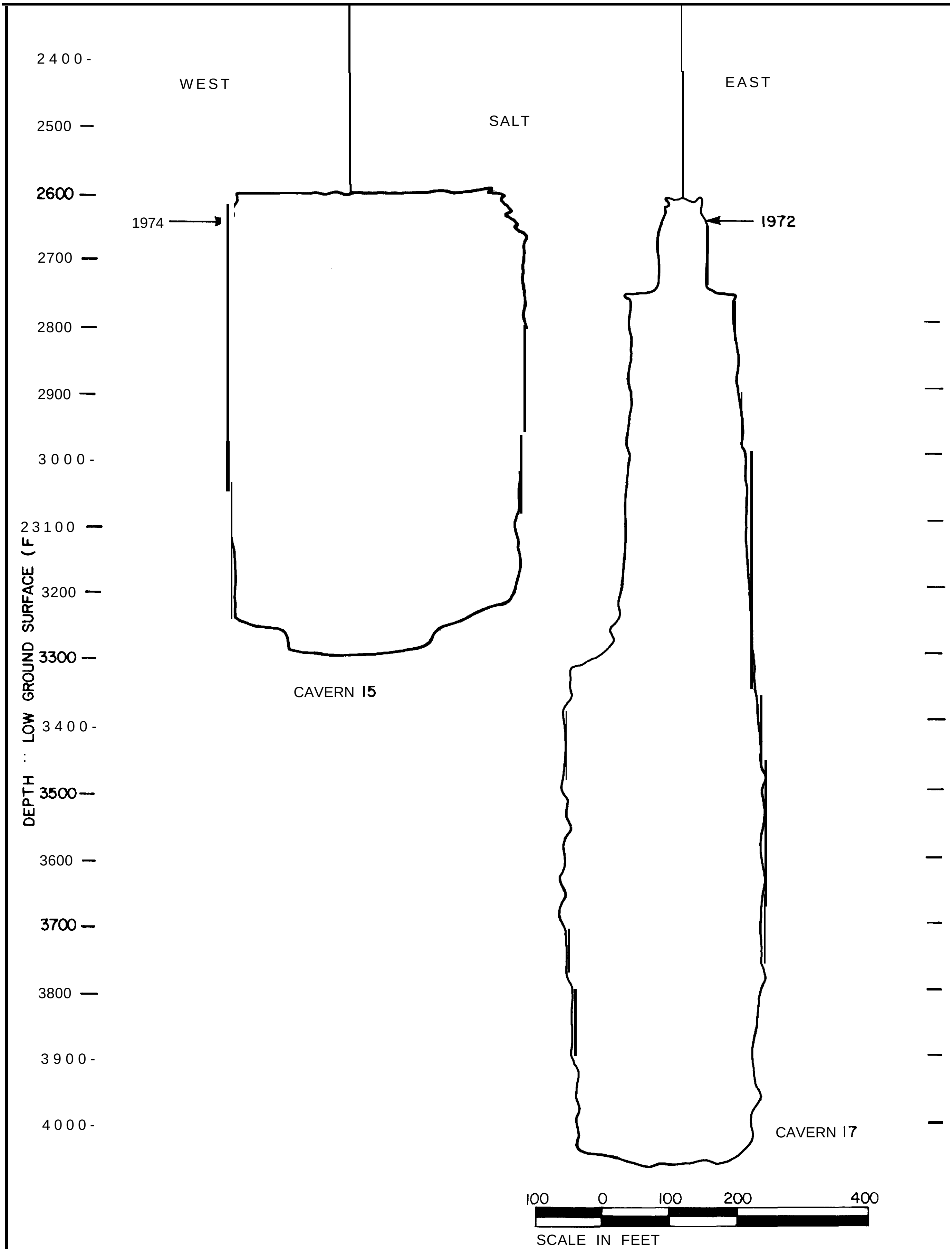
FIG. 6.36



NOTE; DATES REFER TO SONAR SURVEYS

BAYOU CHOCTAW SPR SITE
SECTION THROUGH CAVERNS 15 & 17

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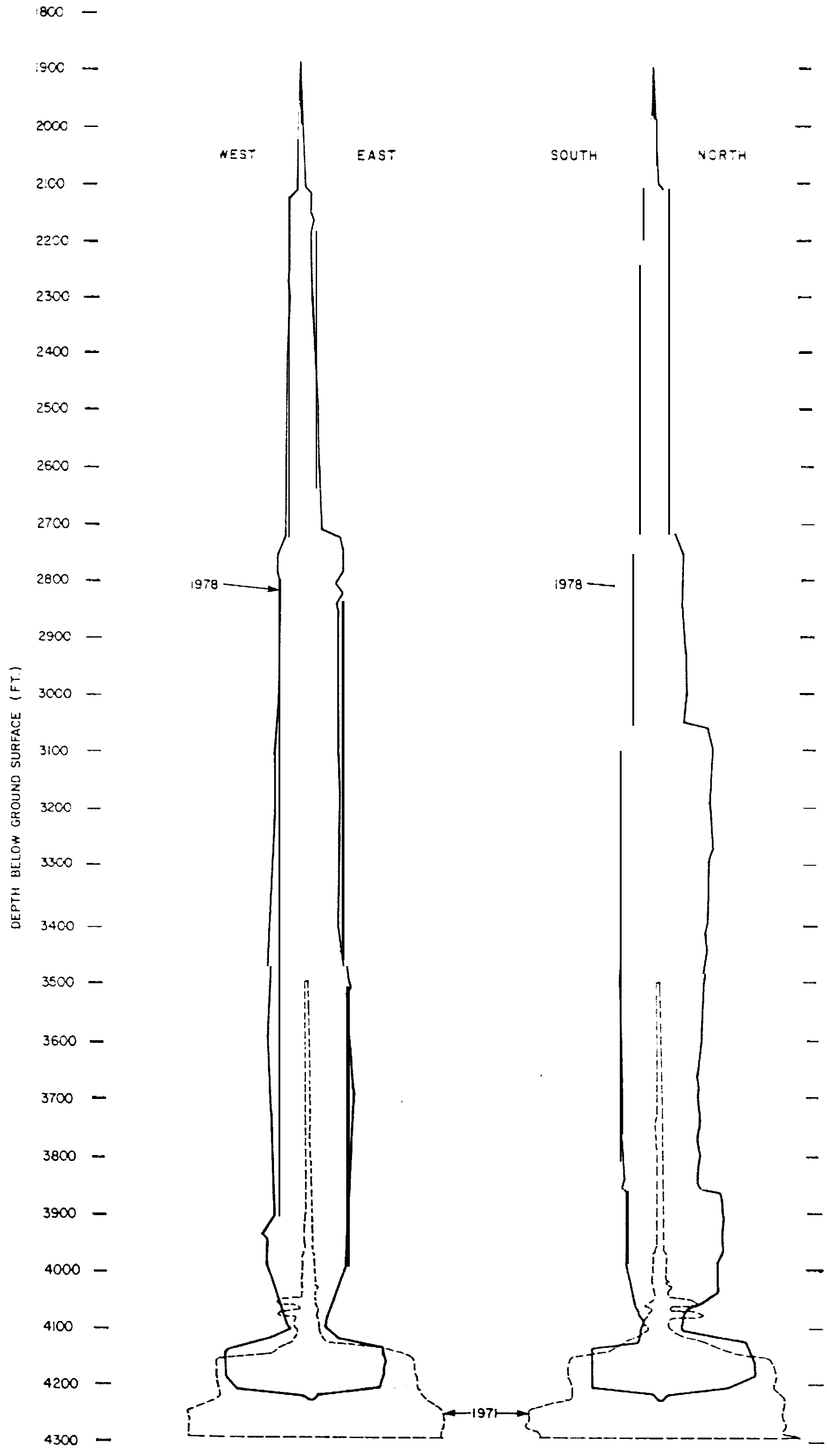
FIG. 6.37

REFERENCE : PB- KBB, 1978 b & 1978 i



NOTE: DATES REFER TO SONAR SURVEY
DATE DRILLED 1967
ELEVATION (MEAN GULF LEVEL) · + 6.0 FEET
TOP OF CAPROCK : 430 FEET
TOP OF SALT : 857 FEET
ORIGINAL TOTAL DEPTH : 4383 FEET
PRESENT CAVERN TOP (1978): 2100 FEET
PRESENT CAVERN BASE (1978): 4285 FEET
PRESENT CAVERN VOLUME (1978): 8.54 MM BARRELS

REFERENCE: PB-KBB, 1978 b & 1978 i

BAYOU CHOCTAW SPR SITE
PROFILES OF CAVERN 18

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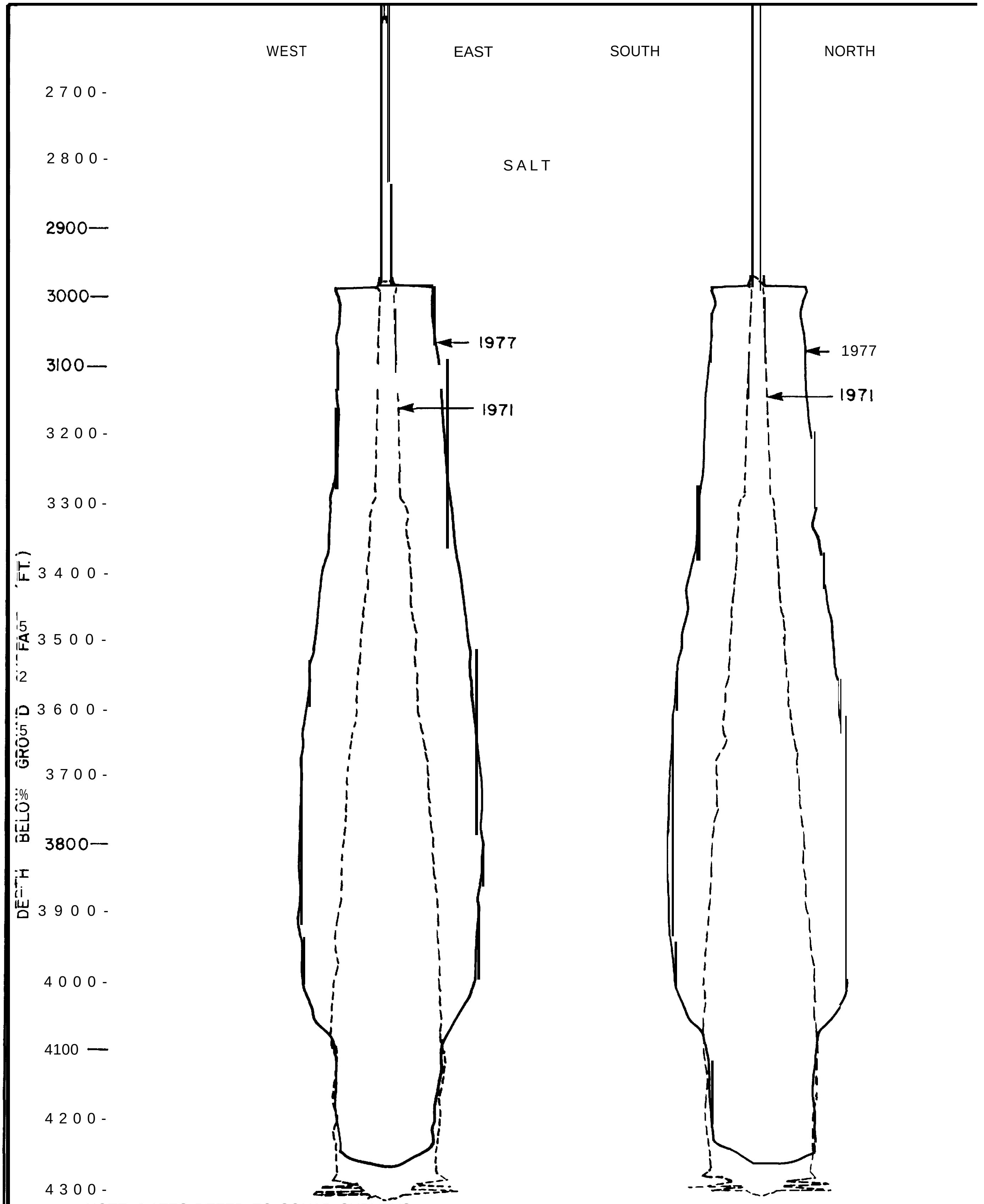
FIG. 6.



NOTE: DATES REFER TO SONAR SURVEYS
DATE DRILLED : 1967
ELEVATION (MEAN GULF LEVEL) : 8 .0 FEET
TOP OF CAPROCK : 550 FEET
TOP OF SALT: 850 FEET
ORIGINAL TOTAL DEPTH : 4400 FEET
PRESENT CAVERN TOP (1977) 2980 FEET
PRESENT CAVERN TOP (1977) 4270 FEET
PRESENT CAVERN VOLUME (1977) : 7.46 MM BARRELS

REFERENCE PB- KBB, 1978b & 1978 i

100 0 100 200 400
SCALE IN FEET

BAYOU CHOCTAW SPR SITE
PROFILES OF CAVERN 19

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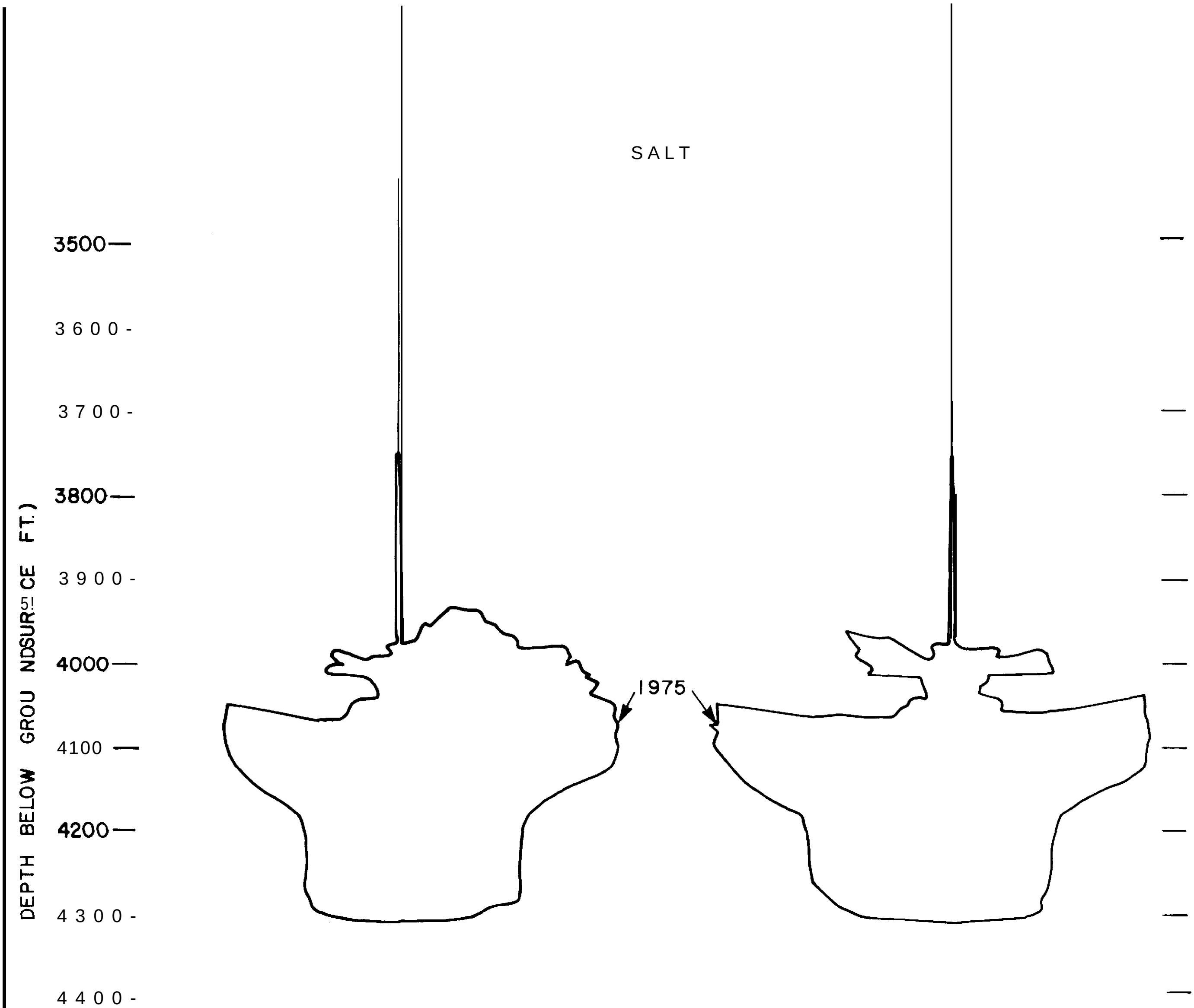

NOTE: DATES REFER TO SONAR SURVEYS
DATE DRILLED : 1970
ELEVATION (MEAN GULF LEVEL) : 7 0 FEET
TOP OF CAPROCK : 500 FEET
TOP OF SALT: 681 FEET
ORIGINAL TOTAL DEPTH : 4452 FEET
PRESENT CAVERN TOP (1978) : 3935 FEET
PRESENT CAVERN BASE (1978) : 4305 FEET
PRESENT CAVERN VOLUME (1978) : 5.2 MM BARRELS

REFERENCE: PB-KBB, 1978b & 1978i

100 0 100 200 400
SCALE IN FEET

BAYOU CHOCTAW SPR SITE
PROFILES OF CAVERN 20

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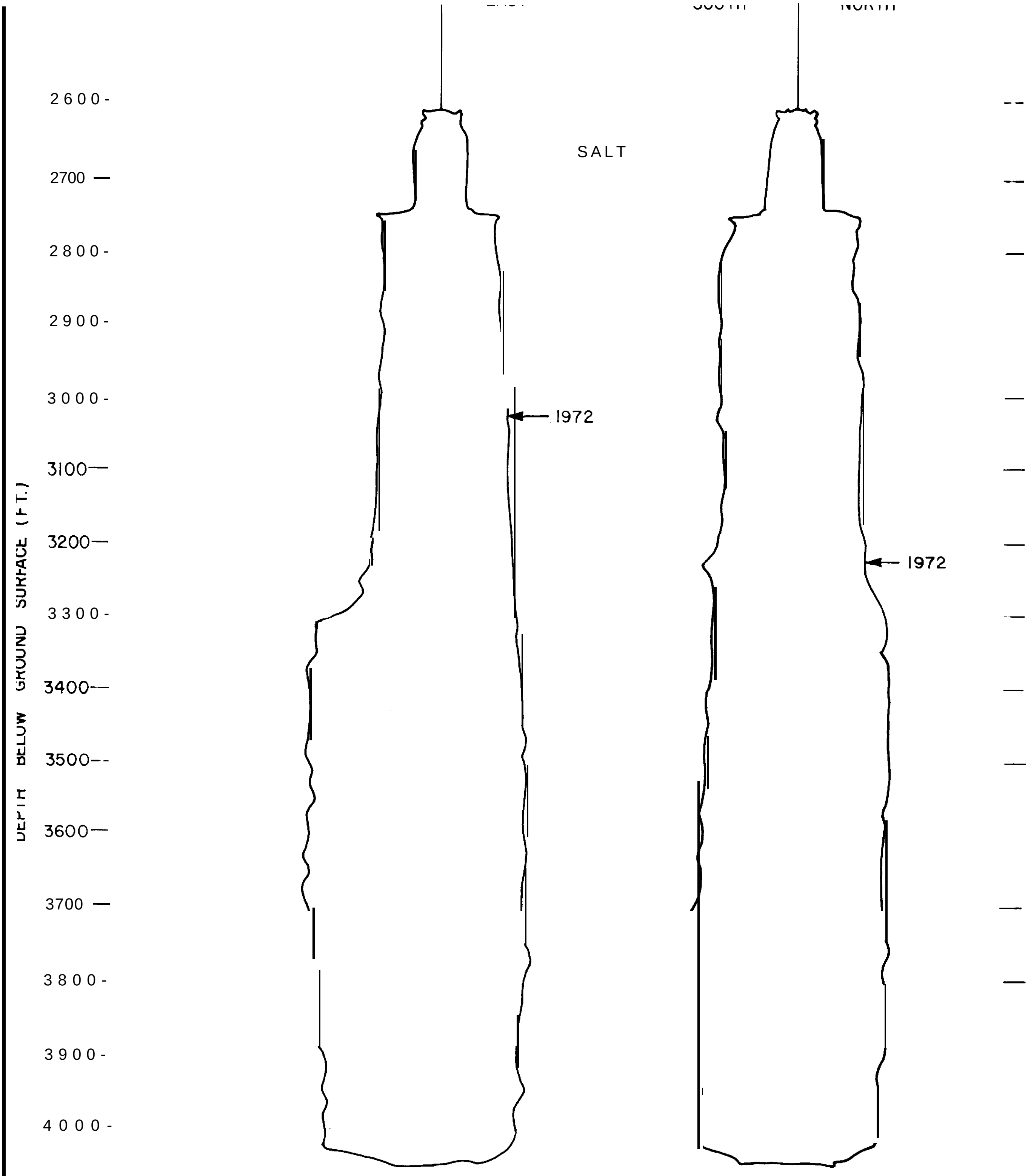
FIG. 6.40



NOTE: DATES REFER TO SONAR SURVEYS
DATE DRILLED : 1955
ELEVATION (MEAN GULF LEVEL) : N/A
TOP OF CAPROCK :
TOP OF SALT:
ORIGINAL TOTAL DEPTH : 4125 FEET
PRESENT CAVERN TOP (1972) 2590 FEET
PRESENT CAVERN BASE (1972) 4050 FEET
PRESENT CAVERN VOLUME (1976) 12.2 MM BARRELS

REFERENCE : PB-KBB, 1978b 8 1978i

100 0 100 200 400
SCALE IN FEET

BAYOU CHOCTAW SPR SITE
PROFILES OF CAVERN 17

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SEPTEMBER 1980

FIG. 6.41

7 - HAZARDS

7.1 - Introduction

This sections addresses the potential impacts on the SPR facilities resulting from hazards. These hazards may be either naturally occurring or resulting from man's activities. The major hazards that have been addressed in this study, which are considered to have the greatest impact on the site, include:

- Hurricanes, high winds and floods
- Earthquakes
- Natural subsidence
- Cavern collapse

These hazards are individually discussed in the following sections.

7.2 - Hurricanes, High Winds, and Floods

Hurricanes passing through southern Louisiana result in high winds, heavy rains and flooding. Hurricanes with winds greater than 100 mph passing through the Bayou Choctaw area occurred in 1964, 1965 and 1971. The yearly risk of hurricanes (winds 74-124 mph) is 6-9% and for tropical cyclones (winds 39-73 mph) is 13-15%. No hurricane with winds greater than 125 mph has occurred in southern Louisiana. Data from Baton Rouge indicate that extreme winds at 30 feet above the ground, with a 50-year recurrence interval, are around 100 mph (SPRO, 1976). These wind velocities may be slightly higher at the site which is closer to the coast.

Flooding in the site area generally occurs in the winter and early spring. To maintain safe water levels and prevent flooding in the Baton Rouge and New Orleans areas, water is diverted from the Mississippi into the Atchafalaya during the peak flow periods. When this occurs, high water levels in the Atchafalaya cause water to back up into its tributaries, flooding the surrounding lowlands. Flood water levels in the canals reach a maximum elevation of +14 feet. These levels can be expected every two years at the site. The average site elevation ranges between +5 and +10 feet.

All existing SPR facilities including pumps, office buildings, computers, well heads and piping fall below the +14 foot flood level. Bayou Choctaw site personnel sandbag specific areas of the site during flood periods. The affects on SPR facilities resulting from flooding would be a temporary operating loss of the site.

7.3 - Earthquakes

The historical record of seismicity in the Gulf Coast indicates that the area is nearly aseismic. Figure 7.1 is a map of earthquake epicenters and major faults in the Gulf Coast area. The closest epicenter to the Bayou Choctaw site was located at Napoleonville, 40 miles to the southeast where an earthquake of Intensity VII (Modified Mercalli) occurred on December 19, 1930. The intensity at White Castle, 15 miles southeast of Bayou Choctaw was V. The estimated intensity felt at the site was IV. This earthquake and two others located southeast of the site appear to be related to the Baton Rouge fault. Figure 7.1 shows part of the trace of this fault and the projection of the fault plane. The Baton Rouge fault is an active growth fault which marks the boundary between erosion to the north and deposition to the south in the Mississippi delta. The site lies south of the fault in an area of minimum deposition. The epicenters lie near the area of maximum deposition where the effect of sediment loading has caused movement along the fault plane, generating earthquakes. Because of the minimum sediment loading over the Baton Rouge fault in the site area, it is unlikely that an earthquake of Intensity VII could be expected at the site. However, even with an earthquake of this intensity, no damage would be expected to well-built structures or underground openings.

7.4 - Natural Subsidence

Allied Chemical Corporation established benchmarks and conducted a subsidence survey at Bayou Choctaw from 1954 to 1971. A review of that data performed by PB/KBB (1978c) showed that survey points not located over a cavern indicated typical subsidence rates on the order of 0.01 to 0.02 feet per year. Larger orders of subsidence (0.03 to 0.05 feet per year) were recorded over the caverns. These readings were frequently averaged over a period of up to seven years. PB/KBB re-established a subsidence survey network over the dome in 1978. The survey included the establishment of both deep and shallow monuments. The results of two surveys, run at four-month intervals, indicated that no subsidence greater than the accuracy of the survey (± 0.06 feet) had occurred. Based on this data, it appears that the rates of subsidence on the dome are small with no unusually anomalous results suggesting cavern collapse.

In March 1980, an access road above Cavern 4 had subsided enough to be underwater, suggesting an order of subsidence of three feet. The cause for this subsidence was not fully known; however, it may be attributed to settlement and compaction of the underlying soils caused by the recently constructed brine ponds in the immediate area. The site is underlain by up to a 60-foot thick clay layer which is found immediately below the ground surface (see Section 4). This material is quite soft and unconsolidated and subject to consolidation under surface loading conditions. Therefore, the construction of any new facilities on the surface may experience some degree of settlement.

In summary, it appears that surface subsidence will not severely affect existing or proposed SPR facilities. However, appropriate geotechnical and foundation engineering designs must be considered prior to the construction of any new facility at the site. Long-term factors to be considered are differential settlements that could result in pipe stress and in foundation problems.

7.5 - Cavern Collapse

The effects of cavern collapse at Bayou Choctaw is well evidenced by the failure of Cavern 7 in 1954 (see Section 6). Any uncontrolled shallow brining operation has the potential for causing cavern collapse. Caverns 4 and 7 and several other caverns on the dome were brined without a "blanket" to protect the roof of the cavern. As a result, brining operations resulted in the erosion of the cavern into the overlying caprock which led to ultimate Cavern 7 failure which caused large-scale ground subsidence.

The greatest present potential for cavern collapse at Bayou Choctaw is Cavern 4. As discussed in Section 6 and shown in Figure 6.31, the cavern roof is at a depth of 620 feet which extends 30 feet into the massive caprock zone. As in the case of Cavern 7, the cavern was brined by the airlift method which resulted in loss of cavern pressure and abandonment in 1954.

A series of three sonar surveys have been performed in the cavern: 1963, 1978 and 1980. As stated in Section 6, the most recent surveys show a significant enlargement of the cavern to the west and upwards from the 1963 survey. A comparison of the most recent surveys (1978 and 1980) shows no identifiable changes.

It is impossible to determine if the "enlargement" noted between 1963 and 1978 is real or the result of the limitations of the sonar logging technique used at that time. If enlargement occurred during this time, it must have been caused by the circulation of unsaturated waters in and through the caprock.

Recent surface observations show subsidence on the order of three feet along a newly constructed road over Cavern 4. Whether this subsidence is the result of foundation settlement caused by the newly constructed brine ponds or cavern instability cannot be determined.

Nonetheless, it is prudent to note that the same situations that resulted in the collapse of Cavern 7 are present at Cavern 4. Therefore, continued roof decay and solutioning along the caprock/salt interface caused by groundwater movement can ultimately result in roof collapse and ground failure.

Figure 7.2 shows a hypothetical sequence of cavern failure. In the case of Cavern 7, collapse began at the well head. This may not be the case with Cavern 4 since the greatest erosion of the caprock has occurred along the west side of the cavern.

The surface area that would be affected by the possible failure of Cavern 4 is dependent upon the cavern volume and was estimated using the following assumptions:

- Failure could occur at any point on the roof the cavern;

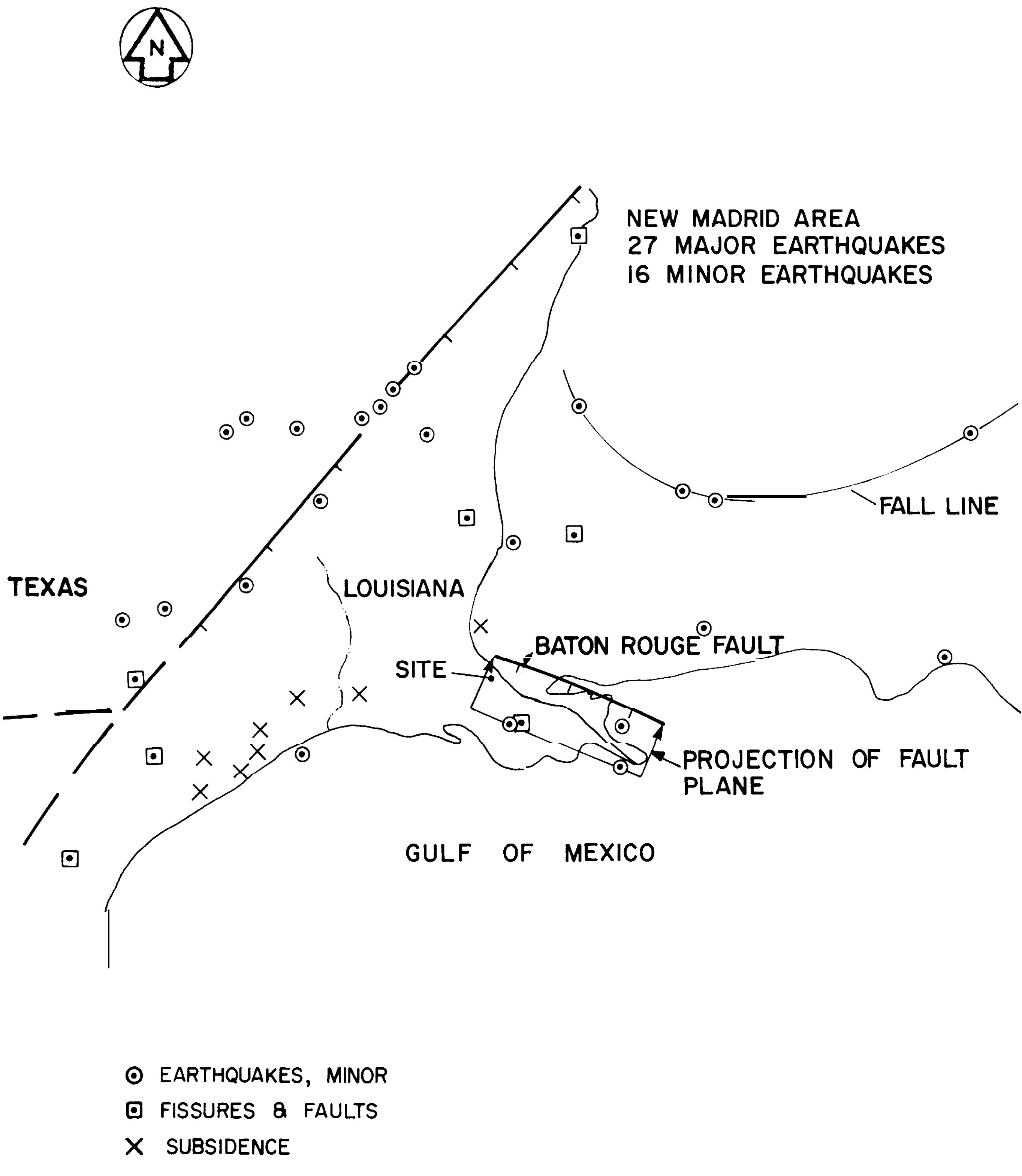
- A conical surface depression;

- The final angle of repose of sediments would be 26° as at Cavern Lake. (This may be conservative in that sediments adjacent to Cavern 4 appear to be more sandy and coarser than those near Cavern 7); and

- The total volume of the cavern would be filled by the overlying sediments.

Based on these assumptions, it was calculated that the maximum cone of surface depression would form an 800-foot diameter circle centered over the point of roof failure. The maximum zone of failure influence is shown on Figure 7.3. This zone delineates the area that could potentially be affected if total failure occurred at any point along the roof. Surface structures beyond this depression would also be affected by long-term creep and slumping of the surface soils into the depression.

Tillerson (1980) calculated that the zone of failure would be an 800 foot diameter circle around the point of failure. A zone of fractures would extend to a diameter of 1,100 feet from the point of failure as shown on Figure 7.3.

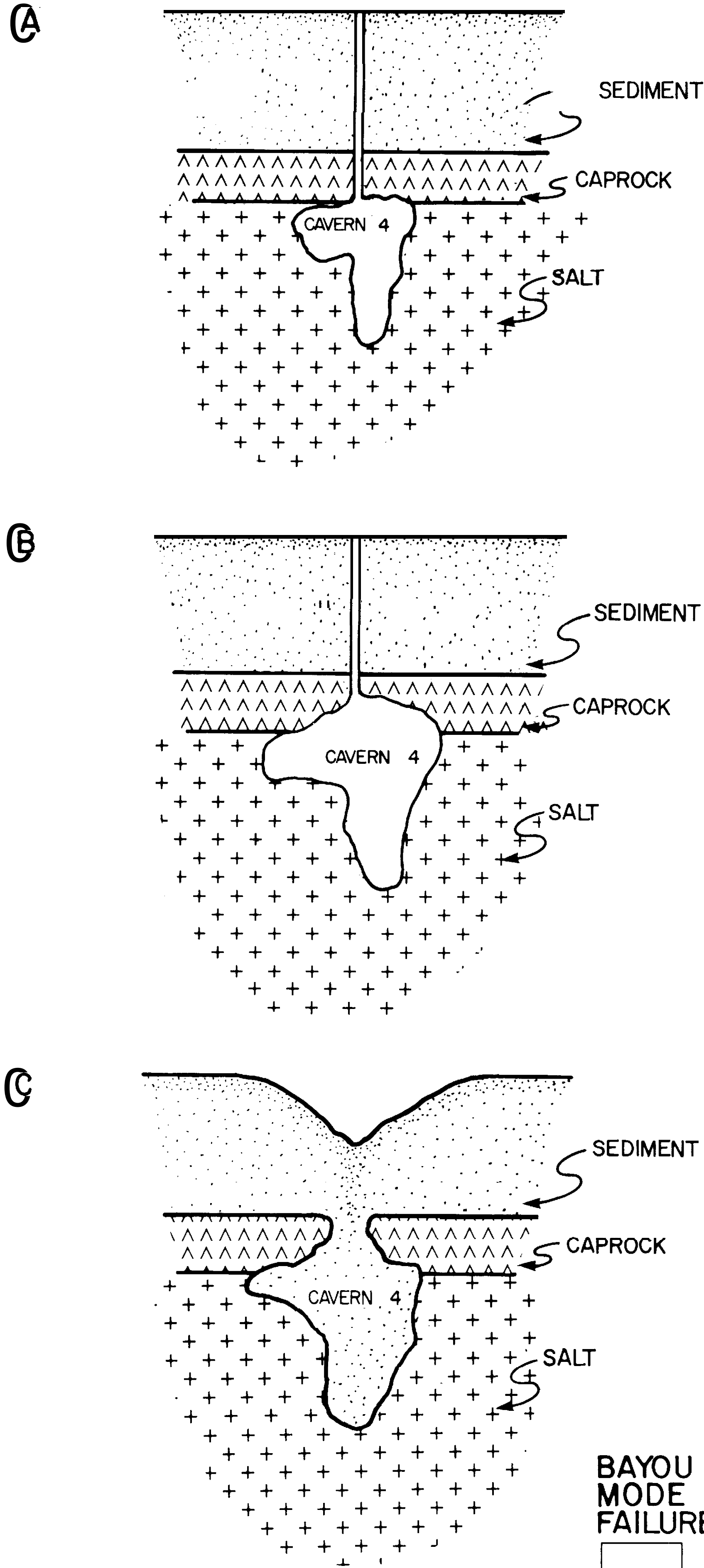


REFERENCE: SHEETS, 1947

BAYOU CHOCTAW SPR SITE
GULF COAST DIASTROPHISM

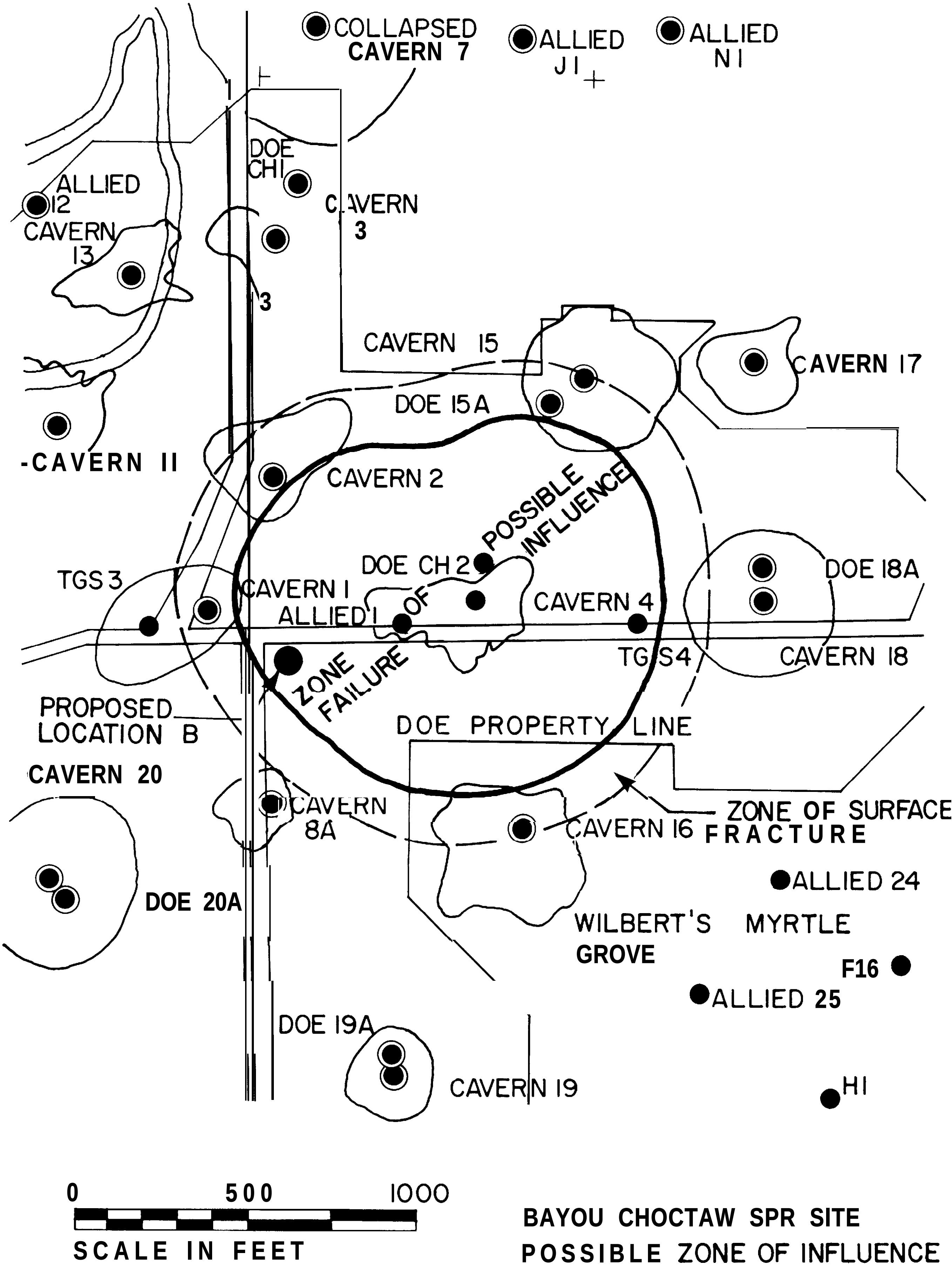
ACRES AMERICAN INCORPORATED
T.R. MAGORIAN
SEPTEMBER 1980

FIG. 7.1



BAYOU CHOCTAW SPR SITE
MODE OF POSSIBLE CAVERN 4
FAILURE

ACRES AMERICAN INCORPORATED
T.R.MAGORIAN
SEPTEMBER 1980 FIG. 7.2



BAYOU CHOCTAW SPR SITE
POSSIBLE ZONE OF INFLUENCE
OF CAVERN 4 FAILURE

ACRES AMERICAN INCORPORATED
T.R. MAGORIAN
SEPTEMBER 1980 FIG. 7.3

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APPENDIX A

This Appendix includes Tables A-1, A-2 and A.3. Table A-1 is a list of depths to the tops of the Pliocene through the Miocene No. 5 Sand. Table A-2 is a list of depths to the tops of the Miocene No. 6 Sand through the Nodosaria blanpiedi zone in the Frio Formation. Table A-3 lists the top to the caprock and salt. Data in these tables is based on the interpretation of logs of more than 300 wells. Well locations are shown on Figure 2.3. To locate data for a particular well, it is necessary first to find on the map the township, range and section in which the well lies. Next the lease must be determined. The lessors name, for example, Morley Cypress Company, and the lease boundaries are marked on Figure 2.3. The tables are arranged in order by township and range, section, lease name, operator and well identification.

TABLE A-1

DEPTHS TO PLIOCENE
THROUGH NO. 5 SAND
BAYOU CHOCTAW SPR SITE

NOTES FOR TABLES A-1 AND A-2

1. Depths in Feet below ground.

2. BTD: Below Total Depth of log.

3. "F" denotes faulted contact.

4. "Fault" denotes unit which is faulted out.

5. *Exact well location unknown.

TABLE A-1
BAYOU CHOCTAW SPR SITE
DEPTHS TO PLIOCENE THROUGH NO. 5 SAND

WELL IDENTIFICATION	Pliocene	Middle Pliocene	Lower Pliocene	Miocene	Sand "A"	0.	0.	0.	0.	0.
Township 4 South, Range 2 East										
Section 64										
Georgia Pacific **Corporation**										
Amoco Production Co.	560	--	--	1305	1915	2295	3050	?	?	3700
Township 6 South, Range 10 East										
Section 15										
C.A. Lorio										
Milton J. Bernos	--	--	--	--	2060	2360	2843	?	3390	3996
Section 25										
R. Palmer										
Wilcans & Secan Oi 1			--	--	2295?	2565	3165	?	3505	4110
Township 6 South, Range 11 East										
Section 17										
Ulmer										
Chevron U.S.A., Inc.	710?	--	--	1595?	1990?	2560	2935	?	3445	4105
Section 31										
Southern **Land** Production Co.										
Humble Oil & **Refining** co.	--	--	--	--	2301	2660	3142	?	3525	4115
Township 7 South, Range 11 East										
Section 3										
Morley Cypress										
Jett Drilling Co.	--	--	--	--	2730	2983	3468	?	3972	?
Section **14**										
A. Wilbert **Sons**										
Monterey Exploration	--	--	--	--	2777	3012	?	?	3920	4920
Section 37										
L. Crochet **Et Al**										
Chevron Oil Co.			--	--	1529	1890	2205	?	2690	3522

TABLE A-1 (Cont'd)

WELL	IDENTIFICATION	Pliocene	Middle Pliocene	Lower Pliocene	Miocene	Sand "A"	0.	0.	0.	0.	0.
Section 35											
	Wilbert Amerada	--	--	--	--	2900	3150	3466	?	4400	5155
Louisiana Clay Products											
	Headington	--	--	--	--	2872	3310	3488	?	4392	4840
Township **8 South, Range 11 East** Section 27											
HEP Development Co.											
	Ethyl Corp.	--	--	--	3130	3535	3780	4107	4895	5258	6045
H. Levert											
	Ladd Petroleum Corp.	--	--	2130	3132	3458	3768	4080	4760	5170	6040
Section 28											
Levert Heirs											
BA 1	**Temple** Hargrove et al	--	--	--	3055	3625	3878	4350	4755	5285	?
BA 1-1											
BA B-1	British American Oil Production Co.	980	--	--	3135	--	3575	3885	4440	4950	5545
BA C-1		1020	?	2090	3080	3545?	3895	4290	4825	5065	?
BA D-1		?	?	2105	3225	3538	3880	4210	4800	5292	5958
BE 2	Brock Exploration Corp.	--	--	2070	3045	3640	3882	4265	4898	5380	?
Penton 1	Penton-Sohio-Southwest Gas	--	--	2275	3108	3598?	3973	4315	4943	5248	5858
Roussel 1	L.J. Roussel Co.	--	--	2070	3025	3525?	3868	4205?	4882	5235	?
Morley Cypress Co.											
BA 1	**Temple** Hargrove **Et Al**	--	--	--	2790	3270	3500	3890	4505	4840	5380
BA 2		--	--	--	2730	3205	3420	3805	4400	4828	5320
BA 3		--	--	--	3012	3240	3410	3705	4373	4715	5285
BA 4		--	--	--	2860	3255	3515	3900?	4595?	5070	5465
BA 5		--	--	--	2860	3355	3640	4005	4685	4935	5395
BA 6	British **American Oil Production Co.**	833	--	1908	2630	3112	3340	3568	4352	4673	?
BA 7		--	--	2135	2671	3160	3375	3670	4205	4495	5067
BA 8		985		2050	2605	3080	3280	3450	4045	4998	5050
BA B-1		--	--	--	2983	3392F	3640	3955	4545	4920	5575
BA B-2		--	--	--	2890	3358	3648	3965	4675?	5016	5624

TABLE A-1 (Cont'd)

WELL IDENTIFICATION		Pliocene	Middle Pliocene	Lower Pliocene	Miocene	Sand "A"	Sand 0.	Sand 0.	Sand 0.	Sand 0.	Sand 0.
BE 9	Brock Exploration Corp.										
BE 10		--	--	--	2750	3198	3445	3717	4475	4945	5346
BE 11		--	--	--	2790	3316	3574	3948?	4478	4865	5735
BE 11-1		--	--	--	--	--	--	--	--	--	
BE 12		--	--	--	2950	3395	3690	4098	4753	5090	5695
c 2	Carter Oil Co.	--	--	--	2895	3390	3680	3970	4690	5030	5575
c 3		--	--	--	--	--	3562	3965	4702	5030F	5560
c 3-1		--	--	--	--	--	--	--			--
c 4		--	--	2005	2745	3260	3420	3640	4480	4695	5250
c 5		--	1620	2135	3155	3420	3680	4020	4885	5175	5745
Section 29											
Morley Cypress **Company**		--	--	--	--	--	--	--	--	--	
c 1	Standard Oil **of Louisiana**				2930	3400	3655	4035	4740?	4990	5460
E.B. Schwing											
BA 1	**Temple** Hargrove et al	--	--	2160	2900	Fault	3395?	3670	4480	4930	5370
BA 1-1		--	--	--	--	--	--	--	--	--	--
BA A-2		--	--	2375	3145	3425	3738	4065	4750	5125	5493
BA A-2-1		--	--	--	--	--	--	--	--	--	--
BA A-2-2		--	--	--	--	--	--	--	--	--	--
BA A-3		--	--	2560	3165	3468	3752	4155	4740	5130	5698
BA C-1		1015	1680	2190	3090	3568	3830	4155	4880	5145	5760
BE 1	Brock Exploration **Corp.**	--	--	--	3120	3614	3838	4230	4870	5198	5590
BE A-4		--	--	2290	2765	Fault	Fault	3130F	3738	4553?	5060
LC 1	**Louisiana** Oil Crusaders	--	1630	2150	3060	3475	3750	4100	4670	5040	5480
LC 2		--	--	--	3050	3460	3725	4095	4700	5055	5450
LC 3		--	--	--	3060	3510	3720	4055	4730	5110	5560
LC 4		--	--	2495	3120	339cF	3645	4070	4655	5070	?
LC 5		--	--	--	3070	3480	3755	4110	4725	5022	5568
LC 6		--	--	--	--	--	--	--	--	--	--
Strata 1	Strata Energy Inc. & Crystal Oil Co.	--	--	--	--	3620	3918	4255	4903	5162	5895
Section 30											
Wilbert & **Son Et Al**											
	Shell Oil Co.	960	1413	2182	3220	3545	3804	4140	4803	5208	6018
Section 37											
Baist Cooperage & Lumber Co. **In.**											
	R. Lacy, Inc.			--	--	3156?	3600	3911	?	4962	5792

TABLE A-1 (Cont'd)

WELL IDENTIFICATION	Pliocene	Middle Pliocene	Lower Pliocene	Miocene	Sand "A"	Sand No. 1	Sand No. 2	Sand No. 3	Sand No. 4	Sand No. 5
Section 39										
J.H. Schwing										
Martin Exploration Corp.	--		--	3048	3440	3809	4158	4742	5270	6065
Section 41										
E.B. Schwing, Jr.										
Pan American Petroleum Corp.	--	--	--	--	3382	3902	4205	4905	5365	6190
Pan American Reentry (Fortune & Hodges Inc. & G.H. Refining Inc.)										
Wilbert & Sons Lumber Co.										
Lea & Associates	--	--	--	--	--	3835	4208	4925	5357	6125
Section 42										
E.B. Schwing										
Dynamic Exploration Inc.	--	--	--	--	3385	3775	4085	4615	5218	5998
Dynamic Exploration Inc. (Baist Cooperage) (sidetrack of above hole)	--	--	--	--	--	--	--	--	--	5998
LVO Corp. & Carl Oil & Gas Co.	--		--	--	3408	3800	4175	4802	5256	6045
Section 53										
J. H. Schwing										
Martin Exploration Co.	--	--	--	--	3468	3798	4145	4858	5260	6085
Township 8 South, Range 12 East Section 37										
Grace										
S. J. Recile	880	1395	2060	2965	3490	3732	4099	4595	5040	5805
Township 8, South, Range 13 East Section 3										
Australia Planting Co.										
Shell Oil Co.	710	1387	1982	2868	3490	3685	3990	4510	4848	5710

TABLE A-1 (Cont'd)

WELL IDENTIFICATION		Pliocene	Middle Pliocene	Lower Pliocene	Miocene	Sand "A"	Sand O.	Sand O.	Sand O.	Sand O.	Sand O.
Township 9 South, Range 11 East											
Section 7											
J.A. Wilbert et al											
	Aluminum Co. of America	--	--	--	3320	3598	4020	4348	4973	5538	6415
Section 8											
A. Wilbert **Sons**											
	Aluminum Co. **of** America	888	1385	2110	3230	3590	4075	4405	5092	5530	6392
Section 51											
Schwing Lumber & Shingle Co.											
	F.A. Callery	--	--	2395	3155	3665	4065	4465	5245	5735	6600
Section 52											
Gay Union Corp.											
c 1	Standard Oil **of Louisiana**	--	--	--	--		--	--	--		--
c 2		--		--	--	--	--	--	--	--	--
c 3		--	--	--	--		--	--	--		--
c 4		--	--	--	--	--	--	--	--	--	--
c 5		--	--	--		--	--	--		--	--
C 6		--		--	--	--	--		--	--	--
C 6-1		--	--	--			--	--	--	--	--
c 7		--	--		--	--	--	--		4520	5045?
c 7-1		--	--	--	--	--	--	--	--	--	--
C 8		995	1555	2190	2800	3218	?	3660	4392	4700	5538?
C 8-1		--	--	--		--	--	--	--	--	
c 9		--		--		2490?	3090	3465	7	4060	7
c 10	Carter Oil Co.	--	--	2210	2440	3130	3350	3590	3990	4270	5050
c IO-I		--	--	--	--		--		--	--	--
c 11		935	1565	2365?	2845	3465	?	4060	4610	5090	?
c 12		--	1485	2160	2620	3300	3575?	3832?	4360	4845	5610
c 13		--	--	2380		3422?	3915	4075?	4595	4998	
c 13-1		--	--	2390	?	3433	3915	4075?	4590	4999	?
c 14		--		--	--	--	2890	3100	BTD	--	--
c 15		930	1465	2155	2715	3195	3440	3682	4335	4770	BTD
C 16		1145	--	Fault	2972		3	4000?	4499	4949	5540
c 17		1078	1512?	2150?	2762	3260		3830?	4302	4770	5535
C 18		1062	1654	2315	2952	3485	3740	4140	4710	5175	7

TABLE A-1 (Cont'd)

WELL IDENTIFICATION		Pliocene	Middle Pliocene	Lower Pliocene	Miocene	Sand					
						"A"	0.	0.	0.	0.	0.
c 19		1058	?	2345	3032	3480?	3715	4098	4660	5078	?
c 20		1040	1578	2245	2740	3295	3555	3745	4325	4758	?
c 21		1060	--	2300	3002	3530	3815	4095	4638	5020F	5580
c 21-1		--	--	--	--	--	--	--	--	--	--
c 21-2		--	--	--	--	--	--	--	--	--	--
C 21-3		--	--	--	--	--	--	--	--	--	--
c 22		1010	1625?	1990	2880	3445	3715	4060	4518?	5130	?
C 23			--	2195	2681	3106	3320	3825	4045	4240	5000
C 23-1		--	--	--	--	--	--	--	--	--	--
C 24		--	--	2308	2778	3310	3560	3840	4530	4875	5315?
C 25		--	--	2245	2855	3375	3650	3950	4635	5103	5180F
C 26		--	--	1480	1955	2560?	2910	3075	3500	3650F	BTD
C 27		--	--	2105	2648	3158	3405?	3670	4258	4668	5180
C 28		--	--	--	--	--	--		--	4270	BTD
C 29		--	--	1680	2198	2550	3095	3245	3745	4008	--
c 30		1110	1705	2355	2870	3298	3605	3875	4350	4540	5410?
c 31		--	--	1620	--	--	3015?	3135	--	3800F	--
C 32		--	--	2313	2790	3395	3665	3970?	4430	4730	5315
c 33		--	1455	2247	2705	3040	3245	3460?	Fault	4082	4828
c 34		--	1395	1998	2670	2978	3130	3495	?	3876	4510?
c 35		--	1342	1965	2485	2945	3135	3570	3905?	4125?	?
C 36		--	--	1662	2100	2705	3045	3200	3718F	4178	
c 37		--	--	1715	2145	3045	?	?	3805	3865	2703
C 38		--	--	1560	2050	3033	3145	?	3490	3660	4250?
c 39	Humble Oil & Refining Co.	--	1468	2148	2782	3078	3310	3510	?	4075	4805
c 40		--	1535	2105	2750	3173	3412	3678	4188	4447	5065
c 41		998	1370	2089	2480	?	2990	3215	?	3750	BTD
C 42		--	--	2255	2770	3158	3450	3638?	4120	4240?	5125?
c 43		--	1545	2285	2825	3230	3505	3762	4272	4606	BTD
c 44		--	--	2145	2845	3514	3724	4050	4630?	4985	5445
c 49				2332	3018	3585?	3915	4280	4970?	5286	6043
c 50	Texas Gas Exploration Corp. (Gay Mineral Corp.)	--	--	--	--	--	--	--	--	--	--
c 51						3570	Fault	4105	4785	5232	5942
Gulf 1	Gulf Refining Co. & Gulf Producing Div.	--	--	--	--	3202	3480	3898?	4405?	4810	5345?
Gulf 1-1		--	--	--	--	--	--	--	--	--	--

TABLE A-l (Cont'd)

WELL		Middle	Lower		Sand					
IDENTIFICATION	Pliocene	Pliocene	Pliocene	Miocene	"A"	0.	0.	0.	0.	0.
Department of Energy										
DOE CH 1 (Core Hole 1)	BTD	--	--	--	--	--	--	--	--	--
DOE CH 2 (Core Hole 2)	BTD	--	--	--	--	--	--	--	--	--
Cavern 2	BTD	--	--	--	--	--	--	--	--	--
Cavern 3	BTD	--	--	--	--	--	--	--	--	--
Cavern 4	BTD	--	--	--	--	--	--	--	--	--
Allied 5	BTD	--	--	--	--	--	--	--	--	--
Allied 6	BTD	--	--	--	--	--	--	--	--	--
Allied 8	BTD	--	--	--	--	--	--	--	--	--
Cavern 8A	BTD	--	--	--	--	--	--	--	--	--
Allied 9	BTD	--	--	--	--	--	--	--	--	--
Cavern 15	BTD	--	--	--	--	--	--	--	--	--
DOE 15 A (Cavern 15 reentry)	BTD	--	--	--	--	--	--	--	--	--
Cavern 18	BTD	--	--	--	--	--	--	--	--	--
DOE 18A (Cavern 18 reentry)	BTD	--	--	--	--	--	--	--	--	--
Cavern 19	BTD	--	--	--	--	--	--	--	--	--
DOE 19A (Cavern 19 reentry)	BTD	--	--	--	--	--	--	--	--	--
Wilbert Minerals Corps.										
Allied 1 Allied Chemical Corp.										
Cavern 7	BTD	--	--	--	--	--	--	--	--	--
Cavern 16	BTD	--	--	--	--	--	--	--	--	--
Cavern 17	BTD	--	--	--	--	--	--	--	--	--
Allied 24	BTD	--	--	--	--	--	--	--	--	--
Allied 25	BTD	--	--	--	--	--	--	--	--	--
J 1 (Wilbert underground storage)	BTD	--	--	--	--	--	--	--	--	--
N 1	BTD	--	--	--	--	--	--	--	--	--
UTP 1 (Union Texas Petroleum)	BTD	--	--	--	--	--	--	--	--	--
F 1 Freeport Sulphur Co.	895	1460	1985	2545	3034	3228	3350?	3920	4340	?
F 16	955	BTD	--	--	--	--	--	--	--	--
F 20 Freeport Oil Co.	755	1385	1935	--	3118	?	3380	3750F	4055	BTD
F 22	800	1365	1925	?	3035	?	3280	3730	4165	BTD
F 23	--	1407	1930	--	3060	?	3425?	3880?	4250	4860?
F 24	--	1383	2023	--	3130	3378	3490	3945	4260	BTD
F 24-l	--	--	--	--	--	--	--	--	4265	BTD
F 26	--	1430	2005	--	3020	3210	3470	3710	3930	?
F 29	--	1345	1970	--	2955	3098	3375	?	3745	BTD
F 30-I	--	--	--	--	--	--	--	--	--	--
F 30-2	--	--	--	--	--	--	--	4150?	4435	BTD
F 31	840?	1370	1920F	2445	3020	3220	3410?	3925	4160?	4670
F 32	--	1322	1950	?	2950	?	3348	3675	3955	BTD
F 33	--	1345	--	2190	--	--	--	3680	3890	BTD
F 33-l	--	1345	--	2190	--	--	?	3670	3900	--
F 35	--	1398	1868	2398	3000	3340	3585	4045F	4480	BTD
F 37	--	1418	1932	?	3042	?	3245	3885	4255	?
F 38	--	1445	2150	--	3070	Fault	3235	3602	3980	?
F 39	790	1310	1790	2155	2895	3195	3360	3720	3960F	BTD

TABLE A-l (Cont'd)

WELL IDENTIFICATION	Pliocene	Middle Pliocene	Lower Pliocene	Miocene	Sand "A"	Sand 0.	Sand 0.	Sand 0.	Sand 0.	Sand 0.
F 40	775	1270	1668	2105	?	?	3315	BTD	--	--
F 41	--	1328	1788	2395	?	?	2935	3702	3902	?
F 42	--	--	1555	?	2715	?	2885	3495	--	BTD
F 42-l	--	--	--	--	--	--	--	3475	3860	4645
F 43	--	1160	1720	2255	?	2960	3162	3678	4425	?
F 44	--	1175	1715	2235	?	2910	3115	3625	3975	4625
F 45	--	--	2605?	BTD	--	--	--	--	--	--
F 46	--	1355?	BTD	--	--	--	--	--	--	--
F 47	843	1574	1950	BTD	--	--	--	--	--	--
F 48	--	--	--	--	--	--	--	--	--	--
F 49	841	1398	1872	BTD	--	--	--	--	--	--
F 50	820	BTD	--	--	--	--	--	--	--	--
F 52	--	1405	1950	?	3055	?	3295	3835	4250	?
F 54	855?	1240	1875	2675	3000	BTD	--	--	--	--
F 56	--	--	2110	2842	3230	3485	3753	4348	4715	5385?
F 58	--	1375	1960	2850	3095	?	3347?	3895	4275	BTD
F 59	810	BTD	--	--	--	--	--	--	--	--
F 59-1	830	--	1580	2000	Fault	2595F	2830	3250?	BTD	--
F 71	780	--	--	2770	BTD	--	--	--	--	--
F 72	--	--	2255?	BTD	--	--	--	--	--	--
F 82		--	2170	2845	3385	3670	4130	4648	5055	?
Wilbert 's Myrtle Grove										
c 1 Standard Oil of Louisiana	--	--	--	--	--	--	--	--	--	--
c 2	--	--	--	--	--	--	--	--	--	--
c 3	--	--	--	--	--	--	--	--	--	--
c 4	--	--	--	--	--	--	--	--	--	--
c 5		--	--	--	--	--	--	--	--	--
C 6		--	--	--	--	--	--	--	--	--
C 7		--	--	--	--	--	--	--	--	--
C 8	--	--	--	--	--	--	--	--	--	--
C 8-l	--	--	--	--	--	--	--	--	--	--
C 8-2	--	--	--	--	--	--	--	--	--	--
C 8-3	--	--	--	--	--	--	--	--	--	--
c 10 Carter Oil Co.	--	1340	1905	?	3005	?	3360	3740	4010?	BTD
c 10-I	--	--	--	--	--	--	--	--	--	--
c IO-2		--	--	--	--	--	--	--	--	--
c 19	--	--	1280	1720	BTD	--	--		--	--
c 20	--	1320	1860	--	2865	2995	3120	3395	BTD	--
c 21	--	1345	1980	?	2905	--	3050	3405	BTD	--
c 22	--	--	--	--	--	--	--	--	--	--
c 22		--	--	--	--	--	--	--	--	--
C 23	--	1365	1910	?	3142	BTD	--	--	--	--
C 24		--	1410	1934	?	2900	3102	BTD	--	--
C 24-l	--	1285	1975	?	2872	BTD	--	--	--	--
C 24-2	--	--	--	--	--	--	--	--	--	--
C 25	885	1270	BTD	--	--	--	--	--	--	--
C 25-l	885	1187	--	2650	BTD	--	--	--	--	--

TABLE A-1 (Cont'd)

WELL IDENTIFICATION		Pliocene	Middle Pliocene	Lower Pliocene	Miocene	Sand "A"	Sand 0.	Sand 0.	Sand 0.	Sand 0.	Sand 0.
C 26		975	1275	2020	2805	3150	--	3540?	4058	4375	BTD
C 26-1		--	--	--	--	--	--	--	--	--	--
C 27		--	--	--	--	--	--	--	--	--	--
C 27 A		--	--	2215?	?	BTD	--	--	--	--	--
C 28		1190	1670	2190	?	3168	3408	3565	?	4485	?
c 30		870	1400	2030	2435	3160	3395	3555	?	4523	BTD
c 31			1385	1920	?	2830	Fault	3210	BTD	--	--
C 32		--	--	1764	BTD	--	--	--	--	--	--
c 33			1370	1898	?	3045	?	3338?	3695	3930	BTD
c 34			1370	1902	?	2998	?	3248	3614	4015	BTD
c 35		--	1345	1908	?	2975	?	3250	3650F	BTD	--
C 36		--	1395	1925	?	3025	?	3202	3850	4074	4570?
c 37		--	1375	1895	?	2973	?	3140	3595	3805	BTD
C 38			1300	1920	--	2950	3072	3295	?	3578	4120F?
c 39		--	1380	1945	?	3050	?	3290	3787	4195	4500F?
c 40		858	1337	1975	2690	2998	Fault	3140	3955	--	--
c 41		--	1260	1840	?	2810	?	3410	BTD	--	
C 42	Humble Oil & Refining Co	--	1400	1928	--	3028	?	3205	3845	4058	4445
c 43		--	1420	1995	?	2990	?	3172	?	3885	4405?
c 44	Texas Gas Exploration Co.	--	1375	1895	?	2995	?	3160	3660	3863	BTD
H I	T.M. Hoffman'	--	1378	1895	BTD	--	--	--	--	--	--
H 2		--	1390	1872	?	3030	?	3360	BTD	--	--
H 3		--	--	--	--	--	--	--	--	--	--
H 4		--	--	--	--	--	--	--	--	--	--
PE 7	Precise Exploration Co.	--	--	--	2045	BTD	--	--	--	--	--
TGS 4	Texas Gulf Sulphur	--	--	--	--	--	--	--	--	--	--
Section 53											
E.B. Schwing et al											
BA B-1	Temple Hargrove et al	915	1460	2145	3040	3430	3508	3885	4660	4930	5440
BA B-2		--	1720	2325	3130	3460	3660	3925	4715	4975	5424
BA B-3		--	--	2330	3068	3467	3660	3943	4650	4920	5367
BA B-4		--	--	2090	2933	3458	3705	3895	4528	4945	5318
BA B-5		--	1495	2180	2930	3540	3755	3988	4605	5025	5613
BA B-5-1		--	--	--	--	--	--	--	--	--	--
BA B-6		--	--	2120	2982	3510	3745	3986	4650	4955	5595

TABLE A-1 (Cont'd)

WELL IDENTIFICATION	Pliocene	Middle Pliocene	Lower Pliocene	Miocene	Sand "A"	0.	0.	0.	0.	0.
BA B-7 British American Oil Production Co.	--	--	2135	3015	3553	3762	3985	4695	4992	5660
BE 2 Brock Exploration Corp.	--	--	--	--	--	--	--	--	--	--
Choctaw 1 Choctaw Oil Co.	980	1530	2160	3080	3565	3815	4105	4715	5025?	5648
Hall & Damson 1 Brooks Hall & Damson Oil Co.	--	--	--	3223	3775	3985	4305	4808	5280	6150
State 1 Temple Hargrove &			2180	2970	3490	3745	3968	4545	4968	5572
Freeport Sulphur Co.	--	--	--	--	--	--	--	--	--	--
Texas 1 The Texas Co.	--	--	--	3260	3495	3830	4155	4665	5055	5895
Texas 2	--	--	--	3040	3578	3794	4063	4614	5144	5798
Texas Levy 1	--	--	--	--	3465	3670	3955	4580	5020	5658
Department of Energy										
Cavern 1	BTD	--	--	--	--	--	--	--	--	--
Cavern 10	BTD	--	--	--	--	--	--	--	--	--
Cavern 11	BTD	--	--	--	--	--	--	--	--	--
Allied 12	BTD	--	--	--	--	--	--	--	--	--
Cavern 13	BTD	--	--	--	--	--	--	--	--	--
Cavern 20	BTD	--	--	--	--	--	--	--	--	--
DOE 20A (Cavern 20 reentry)	BTD	--	--	--	--	--	--	--	--	--
Wilbert Minerals Corp										
F 2 Freeport Sulphur Co.	--	--	--	--	--	?	3850?	4265?	?	?
F 3	885	1420	2040	2910	3178	3410	3660	4590	4840	5350
F 4	840	1275	1995	2905	3170F	3360	3698	4400	4718	5280
F 5	855	1340	1975	Fault	3178	3425	3725	?	?	5052
F 6	850	1351	2076	2940	3315	3455	3730	4455	4810	5360
F 7	934	--	2105	3035	Fault	3565	3895	4506	4827	5405
F 8	--	--	2120	3025	3320	3518	3895	4820	4964	5390
F 9		--	2120	3002	3280	3490	3940	4780	4970	5538
F 10	760	1466	1970	2795	3296	3430	3692	4288	4828	5355
F 11	--	--	--	2515	2825	3062	3405?	4008	4248	?
F 11-1	--	--	--	--	--	--	--	?	4255?	?
F 11-2	--	--	--	--	--	3035	3290F	3905?	4290	BTD
F 12	--	--	--	2695?	3015?	3278	BTD	--	--	--
F 12-1	--	--	--		2855	BTD	--	--	--	--
F 13	--	--	2160	2940	3445	3680?	3898	4540	4980	5592
F 13-1	--	--	2178	2933	3452	3633?	3878	4545	4980	5602
F 14	--	--	2053	2830	3248	3565?	3812?	4322	4795	5414

TABLE A-1 (Cont'd)

WELL IDENTIFICATION		Pliocene	Middle Pliocene	Lower Pliocene	Miocene	Sand “A”	Sand No. 1	Sand 0.	Sand 0.	Sand 0.	Sand 0.
F 15		--	--	2060	2770	3185	3532	3728	4412	4870	5483
F 17		730	1385	1920	2640	3098	3380	3584	4210	4712	5350
F 17-1			--	--	--	--	--	--	--	--	--
F 18	Freeport Oil Co.	865	1440	2125	2830	3285	3660	3860	4575	4955	5552
F 19	Wilbert State Unit	--	--	2115	2920	3442	3578	3878F	4565	4886	5425
F 21			--	--	--	--	--	--	--	--	--
F 25		--	--	--	--	3210	3365	3810	?	4386	BTD
F 25-1			--	--	--	3220?	3445	3858	?	4388	?
F 28			--	--	--	--	--	--	--	4765	--
F 51		--	--	--	--	--	--	--	--	--	--
F 53			--	--	--	--	--	3255	3750?	4135	--
F 55		735	--	--	--	--	3015	3352	3758	4260	?
F 60		--	--	--	--	3000	3425	3590	4201	4720	5068
F 61			--	--	--	--	--	--	--	--	--
F 62		--	--	--	--	--	--	--	--	--	--
F 64		--	--	--		--	--	--	--	--	--
F 64-1		855	1508	2165	2890	3440	?	3935	4555	4998	5595
F 65		--	--	2205	3362	3535	?	4185	4700	5253	5595
F 67		--	1500	2195	BTD	--	--	--	--	--	--
F 68		--	1425	2105	BTD	--	--	--	--	--	--
F 69		--	--	--	--	--	--	--	--	--	--
F 70		--	--	--	--	--	--	2950?	BTD	--	--
F 73	(F11 sidetrack)	--	--	--	2445	--	3035	3290F	3905	4290	BTD
F 74		--	--	--	--	--	--	2895	3620?	BTD	
F 76		--	--	--	2752	3130	3440	3650	4160f	?	4840
F 78		--	--	2105	2960	3305	3505	3905	4806	4941	5430
F 79		--	--	--	2800	3040	?	3210F	4030	4355	4940
F 81		--	--	2365	3158	3463	3696	4000	4815	5098	5601
PE 4	Precise Exploration Corp	--	--	--	--	--	--	--	--	--	--
Wilbert's Myrtle Grove											
c 1	Standard Oil of Louisiana	--	--	--	--	--	--	--	--	--	--
c 9		--	--	--	--	--	--	--	--	--	--
c 9-1		--	--	--	--	--	--	--	--	--	--
c 11	Carter Oil Co.	--	--	--	--	--	--	--	--	--	--
c 12		--	--	--	--	--	--	--	--	--	--
c 12-1		--	--	--	--	--	--	3428	?	BTD	--
c 13		--	--	--	--	--	--	3312?	3670?	BTD	--
c 14		--	--	--	--	--	--	--	--	--	--
c 14-1		--	--	--	--	--	--	--	3675	4060	4895?

TABLE A-1 (Cont'd)

WELL IDENTIFICATION		Pliocene	Middle Pliocene	Lower Pliocene	Miocene	Sand "A"	0.	0.	No.	0.	0.
c 15		--	--	--	--	--	3160	3350	3840	4200?	4540?
C 16		--	--	--	--	2748	?	3510?	3895	4535?	?
C 29		835	1395	2095	BTD	--	--	--	--	--	--
C 29-1		--	--	2060	2855	?	3452	3625	BTD	a-	--
C 29-2		--	--	--	--	--	--	--	--	--	--
TGS 1	**Texas Gulf Sulphur**	--	--	--	--	--	--	--	--	--	--
TGS 2		--	--	--	--	--	--	--	--	--	--
TGS 3		--	--	--	--	--	--	--	--	--	--
TGS 4		--	--	--	--	--	--	--	--	--	--
TGS 5		--	--	--	--	--	--	--	--	--	--
TGS 6		--	--	--	--	--	--	--	--	--	--
TGS 7		--	--	--	--	--	--	--	--	--	--
TGS 8		--	--	--	--	--	--	--	--	--	--
Section 58											
Wilbert & Sons Lumber											
1	**Flaitz** & Mitchell	--	--	2133	3148	3548	4055	4482	5105	5565	6540
2		--	--	2132	3232	3615	4130	4505	5145	5632	6492
Section 60											
Wilbert Minerals Corp											
F 80	Freeport Oil Co.	--	--	2260	3128	3525	3778	4033	4805	5301	5760?
PE 1	**Precise** Exploration Corp	--	--			3675	3976	4218	4922	5396	6105
Section 61											
Wilbert **Minerals** Corp.											
BE 12	Brock Exploration Corp	918	1425	2060	2925	3260	3525	3755	4400	4820	BTD
Cabot 1	**Cabot** Corp	933	1535	2222	3008	3615	3975	4250	4795	5250	6085
C 18	Carter Oil Co.	--	1535	2165	2960	3560	3885	4185	4848	5240	6040
Delta 3	**Delta Development** Corp	985	1435	2070	2942	3308	3645?	3808	4605	5155	5778
F 34	Freeport Oil Co.	--	--	2105	3000	3350	3650	3915	4520	5030	5574

TABLE A-1 (Cont'd)

WELL IDENTIFICATION		Pliocene	Middle Pliocene	Lower Pliocene	Miocene	Sand "A"	Sand 0.	Sand 0.	Sand 0.	Sand 0.	Sand 0.
Section 61											
F 36		--	--	2145	3032	3460	3790	4118	4760	5150	5995
F 57		--	--	2120	2985	3395	3710	3935	4418	4735	?
F 63		--	--	2220	3055	3488	3885	4165	4808	5228	?
F 63-1		--	--	--	--	--	--	--	--	--	--
F 66		--	--	2198	2858	3432	?	4015	4630	5055f	5750
F 77		--	--	2150	3090	3475	3798	4076	4762	4980f	5720
Lone Star 1	Lone Star Production Co	--	--	--	2935	3350	3638	3945	4525	4925	5710
LVO 1	LVO Corp.	--	--	--	3105	3696	3970	4348	5085	5498	6322
Texas Pacific	Texas Pacific Oil Co.	--	--	--	3095	3642	3870	4210	4985	5450	6295
Section 62											
Department of Energy											
DOE 1	Brine Disposal Wells	992	1495	2305	3118	3638	3960	4362	5065	5565	6348
DOE 2		995	1515	2405	3210	3755	4050	4480	5210	5645	6503
DOE 3		955	1500	2388	3230	3754	4048	4405	5295	5615	6465
DOE 4		--	1490	2340	3150	3695	3996	4340	5085	5565	6414
DOE 5		--	1495	2330	3150	3695	4002	4340	5150	BTD	
DOE 6		958	1503	2322	3168	3718	4010	4358	BTD		
DOE 7		--	1495	2310	3155	3690	3980	4335	5122	5595	6455
DOE 8		--	1490	2305	3155	3690	3978	4335	5098?	BTD	
DOE 9		--	1510	2315	3150	3695	4055	4348	BTD		
DOE 10		--	1515	2320	3148	3695	4058	4350	5105	5600	6475
DOE 11		--	1510	2395	3184	3695	3978	4393	BTD	--	--
DOE 12		--	--	2322	3175	3710	4063	4355	5143	5598	6490
Township 9 South, Range 12 East											
Section 61											
Gay Union Corp.											
BA 1	Temple Hargrove et al	--	--	2270	3058	3625	4035	4290	4902	5425	6295
BA B-1	Temple Hargrove & H. Hurt	1040	1615	2298	3118	3630	4060	4353	4920	5365	6190
c 45	Humble Oil & Refining Co	--	--	--	3010	3615	3850	4205	4910	5328	6090
C 46		--	--	2220	3320	3648	3932	4173	4665	5073	5840
C 47		--	--	2195	3012	3605	Fault	3964	4640	5014	5815

TABLE A-1 (Cont'd)

WELL IDENTIFICATION	Pliocene	Middle Pliocene	Lower Pliocene	Miocene	Sand "A"	0.	0.	0.	0.	0.
C 48	--	--	--	3098	3452	3795	4177	4512	5250	6050
Davis 1 Davis Oil Co. & Leben Drilling Inc.	--	--	--	3060	3688	3798f	4140	4682	5116	5910
Section 70										
Wilbert Minerals Corp.										
Weaver C.W. Weaver Drilling Co	--	--	2112	3050f	3560	4031	4450	5260	5605	6486
Section 82										
Wilbert Minerals Corp.										
Delta 2 Delta Development Co. Inc.	970	1385	2098	3066	Fault	3722	4085	4690	5122	5965

TABLE A-2

DEPTHS TO NO. 6 SAND THROUGH
NODOSARIA BLANPIEDI ZONE
BAYOU CHOCTAW SPR SITE

TABLE A-2
BAYOU CHOCTAW SPR SITE
DEPTH TO NO. 6 SAND THROUGH NODOSARIA BLANPIEDI ZONE

WELL IDENTIFICATION	Sand				Hetero-stegina Limestone	Frio Formation	Mio-gypsina Zone	Cibicides Hazzardi Zone	Marginulina Texana Zone	Bolivina Mexicana Zone	Nodosaria Blanpiedi Zone
	No. 6	No. 7	No. 8	No. 16							
Township 4 South, Range 2 West Section 64			4208	5140	5730	5985	6980	7090	7162	7310	
Georgia Pacific Corporation											
Amoco Prod. Co. #1											
Township 6 South, Range 10 East Section 15											
C.A. Lorio											
Milton J. Bernos	4172		4949	6020	6560	7251	7580	7748	8170	8350	8969
Section 25											
R. Palmer											
Wilcans & Secan Oil	4630		5170	6118	6810	7560	7870	8094	8638		8125
Section 37											
L. Crochet Et al											
Chevron Oil Co.	3868		4720	5648	6210	6990	7273	7520	7852	8018	8521
Township 6 South, Range 11 East Section 17											
Ulmer											
Chevron, U.S.A., Inc.	4335	4601	4935	5905	6503	7180		7750	8170	8330	8905
Section 31											
Southern Land Production Co.											
Humble Oil & Refining Co.	4640		5200	6260	6953	7665	781[illegible]	8342	8790	8959	9311

TABLE A-Z (Cont'd)

WELL IDENTIFICATION	Sand 0.	0.	0. 8	0. 6	Hetero-stegina Limestone	Frio Formation	Mio-gypsina Zone	Cibicides Hazard Zone	Marginulina Texana Zone	Bolivina Mexicana Zone	Nodosaria Blanpiedi Zone
Township 7 South, Range 11 East Section 3											
Morley Cypress											
Jett Drilling Co.			5308	6375	7020	7701			8820	9032	9478
Section 14											
A. Wilbert Sons											
Monterey Exploration	4855		5420	6580	7201	7878			9101	9417	9668
Section 35											
Amerada	5365		5998	7238	7842	8472			9558		
Louisiana Clay Products											
Headington	5348		5958	7212	7842	8399			9770	BTD	
Township 8 South, Range 11 East Section 27											
HEP Development Co.											
Ethyl Corp.	6220	6865	7120	8310	8962	9573	9815		10114	10510	11003
H. Levert											
Ladd Petroleum Corp.	6214	6720	6833	8178	8810	4442	9685		10045	10885	11230
Section 28											
Levert Heirs											
BA-1 **Temple** Hargrove et al			6130	6965	7325	7695			8340	BTD	

TABLE A-2 (Cont'd)

WELL IDENTIFICATION		Sand No. (	o.	0.	0. 6	Hetero-stegina Limestone	Frio Formation	Mio-gypsina Zone	Cibicide Hazzardi Zone	Marginulina Texana Zone	Bolivina Mexicana Zone	Nodosaria Blanpiedi Zone
Section 28												
BA 1-1							7560	BTD				
BA B-1	British American Oi 1 Prouduct ion co.	5875	6150	6320	7385	7882	8360	8605	8700	9038	9345	BTD
BA C-1			6190	6365	7485	8015	8310	8580	8715	8910	9410	BTD
BA D-1				6423	7545	7885	8400	8520	8650	8742	9005	BTD
BE 2	Brock Exploration Corp.		6075	6230	7426		8155	8532	8632	8790	9150	BTD
Penton 1	Penton-Sohio Southwest Gas	6065	6393	6657	7845	8325	8852	BTD				
Roussel 1	L. J. Roussel Co.			6225	7390	7645	8115	BTD				
Morley Cypress Co.												
BA 1	Temple Hargrove et al	5540	5732	6080	6955	7190	7675	7885	BTD			
BA 2		5580	5785	5872	6805	Fault	7325	7650	7845	BTD		
BA 3		5588	5806	5968	6815	7273	7550	BTD				
BA 4		5695	6008	6210F	6820	7420	7682	8010	BTD			
BA 5		5558	6048	6210	7175	7305F	7730	8070	BTD			
BA 6	British American Oil Production Co.			5700	6435	6930	BTD					
BA 7		5235		5488	BTD							
BA 8		5290	BTD									
BA B-1		5835	6230	6445	7355	7862	8320	8460	8740	8882	9270	BTD
BA B-2		5810	6008	6345	7377	7890	8258	8510	8684	8780	9075	BTD
BE 9	Brock Exploration Corp.											
BE 10		5570	Fault	5982	6580	7035	BTD					
BE 11		5858	6015	6268	7185	7652	7850	8070	8540	BTD		
BE 11-I"		5858	6105	6265	7150	7665	7818	8040	8530	BTD		
BE 12		5898	6235	6450	7630	8152	8520	8670	9045	BTD		
c 2	Carter Oil Co.	5750	6205	6340	7175	7495	7980	8250	8465	BTD		
c 3		5785	6160	6302	7010	7542	7620	7928	8215	BTD		
c 3-1					-	7532	7590	7902	BTD			
c 4		5505	Fault	5868	6310	6715	BTD					
c 5		5938	6395	6585	7455	8005	850	8850	8190	BTD		

TABLE A-2 (Cont'd)

WELL IDENTIFICATION		Sand O.	Sand O.	Sand 0. 8	Sand 0. 6	Hetero-stegina Limestone	Frio Formation	Mio-gypsina Zone	Cibicides Hazzardi Zone	Marginulina Texana Zone	Bolivina Mexicana Zone	Nodosaria Blanpiedi Zone
Section 29												
Morley Cypress Co.												
Cl	Standard Oil of Louisiana	5640	6160	6320	7390	7535F	7960	8358	BTD			
E.B. Schwing												
BA 1	Temple Hargrove et al	5675	6060	6290	6860	7395	7530	BTD				
BA 1-1*			-		6870	7470	7740F	BTD				
BA A-2		5760	6225	6350	7305	7675	8095	8290	BTD			
BA A-2-1*					7310	7650	7992	8182	8415	BTD		
BA A-2-2*			-		7310	7660	8060	8190	8430	BTD		
BA A-3		6038	6343	6425	7347	7798	8202	8405	8732	9068	9380	BTD
BA C-l		5915	6315	6745	7700	Fault	8222	9080	9312	9600	BTD	
BE 1	Brock Exploration Corp.	5835	6164	6433	7478	7990	8370	8770	BTD			
BE A-4		5455	5895	5985F	6478	6980	7140	BTD				
LC 1	Louisiana Oil Crusaders	5720	Fault	6680	7440	7810	8300	BTD				
LC 2		5685	6115	6600	7220	7705	8170	8390	BTD			
LC 3		5860	6365	6512	7205	7635	8160	BTD				
LC 4			6225	6395	7202	7555	8010	8202	BTD			
LC 5		5735	6215	6720	7365	7845	8150	BTD				
LC 6												
Strata 1	Strata Energy Inc. & Crystal Oil Co.	6177	6590	6792	7825	8433	8958	9201	9498	9680	10432	BTD
Section 30												
Wilbert & Son et al												
	Shell Oil Co.	6238	6785	6890	8155	8968	9455	9715	10035	10190F	10615	BTD
Section 37												
Baist Cooperage & Lumber Co. Inc.												
	R. Lacy, Inc.	6020		6630	8110	8772	9412			10970	11430	BTD

TABLE A-Z (Cont'd)

WELL IDENTIFICATION	Sand No. (	NO.	0. 8	0. 6	Hetero-stegina Limestone	Frio Formation	Mio-gypsina Zone	Cibicide Hazzardi Zone	Marginulina Texana Zone	Bolivina Mexicana Zone	Nodosaria Blanpiedi Zone
Section 39											
J. **H. Schwing**											
Martin Exploration Corp. 2	6390	6825	6999	8315	9083	9712	9955	10258	10778	BTD	
Section 41											
E. B. Schwing, Jr.											
Pan American Petroleum Corp.	6440	6768	6945	7850	9153	9903	10253	10822	11303	11785	
Pan American Reentry (Fortune & **Hodges,** Inc. & **G.H. Refining Inc.)**	--	--	--	--	--	9903	10208	10825	11313	11802	BTD
A. Wilbert & **Sons** Lumber Co. **Lea & Associates** #1	6385	6958	7095	7870	9205	10050	10265	10883	11382	BTD	
Section 42											
E.B. Schwing											
Dynamic Exploration Inc.	6305	6785	6915	8255	9025	9682	9932	10240	11010	BTD	
Dynamic Exploration Inc. (Baist (Cooperage) **(side track of above hole)**	6305	6795	6940	7983	9205	9895	10155	10480	11100	11912	BTD
LVO Corp. & Carl Oil & Gas Co.	6345	6840	6998	7755	9055	9700	9940	10235	10906	11502	BTD

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TABLE A-2 (Cont'd)

WELL IDENTIFICATION	Sand No. 6	Sand No. 7	Sand No. 8	Sand No. 16	Hetero-stegina Limestone	Frio Formation	Mio-gypsina Zone	Cibicides Hazzardi Zone	Marginulina Texana Zone	Bolivina Mexicana Zone	Nodosaria Blanpiedi Zone
Section 53											
J.H. Schwing											
Martin Exploration Co.	6305	6870	6985	7842	9142	9898	10068	10305	10872	BTD	
Township 8 South, Range 12 East Section 37											
Grace											
S.J. Recile	5999	6462	6848	8030	8588	9242	9510	9780	9998	10488	10978
Township 8 South, Range 13 East Section 3											
Australia Planting Co.											
Shell Oil Co.	5918	6375	6812	7939	8422	9036	9290	9560	9782	10310	10699
Township 9 South, Range 11 East Section 7											
J.A. Wilbert et al											
Aluminum Co. of America	6722	7070	7352	8445	9130	9872	10158	10575	11120	11465	12350
Section 8											
A. Wilbert Sons											
Aluminum Co. of America	6742	7175	7415	8623	9335	10115	10428	10865	11532	11870	12205
Section 51											
Schwing Lumber & Shingle Co.											
F.A. Gallery	6840	7375	7565	9028	10430	10722	11045	BTD			

TABLE A-2 (Cont'd)

WELL IDENTIFICATION		Sand No. (	0.	0.	0. 6	Hetero-stegina Limestone	Frio Formatipn	Mio-gypsina Zone	Cibicides Hazzardi Zone	Marginulina Texana Zone	Bolivina Mexicana Zone	Nodosaria Blanpiedi Zone
Section 52												
Gay Union Corp.												
	Standard Oil of Louisiana											
c 7		BTD										
C 8		5765	BTD									
c 9					5030	5450	BTD					
c 10	Carter Oil co.	--	--	5740	6430		6860	7170	BTD			
c 11				6250	6940		7395	7515	7685	7990	8290	8710
c 12			6060	6160	7112	7608	7870	8095	BTD			
c 13				6425	7140		7735	8325	BTD			
c 73-1				6415	7112		7790	8260	8770	BTD		
c 14												
c 15												
C 16		5820	6135	6292		6935	7302	7540	7820	8082	8750	BTD
c 17			5945	6035	6930	7330	7843	8145	8450	BTD		
C 18				5886	6658	6975	7405	7590		7815F	BTD	
c 19				5820	6530	7085	7390			7718	BTD	
c 20				5750	BTD							
c 21		5775	6145	6195	6945	7355	7600	BTD				
c 21-1		--	--	--	6980	7515	7890	BTD				
c 21-2			6145	6192	6755	7150	7450	BTD				
C 21-3*		--	--	6190	6940	7250		7725	BTD			
c 22				5708	6735	--	7336	7667	7948	BTD		
C 23		5210		5720		6250	BTD					
C 23-1												
C 24		5535		6312	6638	7265	BTD					
C 25			5676	5728	6350	6760	BTD					
C 26		--										
C 27			5810	5882	6210	6630	7092	BTD				
C 28												
C 29			4800	BTD								
c 30		5605	6010	6145	6682	6973	7418	7590	--	8160	8485	BTD
c 31												
C 32				5715	6565	6880	BTD					
c 33		5050		5655	6450	BTD						
c 34		4648		5490	BTD							
c 35				5695	BTD							
C 36		4590	BTD									

TABLE A-2 (Cont'd)

WELL IDENTIFICATION		Sand No. (	0.	o.	0. 6	Hetero-stegina Limestone	Frio Formation	Mio-gypsina Zone	Cibicides Hazzardi Zone	Marginulina Texana Zone	Bolivina Mexicana Zone	Nodosaria Blanpiedi Zone
c 37				5450	BTD							
C 38		4615	BTD									
c 39	Humble Oil & Refining Co.	5070	BTD									
c 40		5295	5783	5845	6660	7072	7410	BTD				
C 42		5325	5806	5880	?	6382	6910	7190	7615	BTD		
c 43												
c 44		5623	?	6375	6930	7155	7565	7698	7990	8155	8440	BTD
c 49		6360	Fault	6670F	7785	8110	8663	9198	BTD			
c 50	Texas Gas Exploration Corp. (Gay Mineral (Corp.)											
c 51		6238	Fault	6392F	7445	7550	7937	Fault	8115	8480	9045	9470
Gulf 1	Gulf Refining co. - Gul Producing Div.	5570	6118	6230	7020	7195	7723	8125	?	8610	8975	BTD
Gulf 1-1												
Wilbert Minerals Corp.												
F 1	Freeport Sulphur Co.	?	?	4980	5585?	BTD						
F 16												
F 20	Freeport Oil Co.											
F 22												
F 23		5135?	BTD									
F 24												
F 26		?	?	5280	BTD							
F 30-1		--	--	--	--		--			--	--	--
F 31		4815	5195?	5305	6020	6220?	BTD					
F 33-1*		--	--	5625	BTD							
F 37		?	?	5165	BTD							
F 41		3	?	4495	BTD							
F 42-1		BTD										
F 43			?	4630	BTD							
F 44			BTD									
F 52		?	?	5095	BTD							
F 56		5540	6012	6135	6870	7370	7675	8130	BTD			
F 58		?	?	5668	6370	6762	7070	7330	7725	BTD		

TABLE A-2 (Cont'd)

WELL IDENTIFICATION		Sand No. 6	Sand No. 7	Sand No. 8	Sand No. 16	Hetero-stegina Limestone	Frio Formation	Mio-gypsina Zone	Cibicides Hazzardi Zone	Marginulina Texana Zone	Bolivina Mexicana Zone	Nodosaria Blanpiedi Zone
Wilbert's Myrtle Grove												
C 28		?	?	?	5424	BTD						
C 36		4875	?	5155	BTD							
C 38		4385	BTD									
C 39		BTD										
C 40		--	--	4725	5750?	BTD						
C 42	Humble Oil & Refining Co.	4590	--	5145	BTD							
C 43	*	4620?	?	5160	BTD							
Township 9 South, Range 11 East Section 53												
E. B. Schwing et al												
BA B-1	Temple Hargrove et al	5585	5970	6350	7200	7585	7950	8170	8393	8592	9105	9568
BA B-2		5587	6073	6520	7360	7863	8160	8382	8571	BTD		
BA B-3		5510	5980	6458	7205	7610	8005	8223	8605	BTD		
BA B-4		5490	5985	6325	7265	8155	BTD					
BA B-5		5765	6055	6496	7345	7958	8290	BTD				
BA B-5-1*		--	--	6490?	7362	Fault	7750	7854?	8132	BTD		
BA B-6		5760	6200	6385	7330	7780	8122	BTD				
BA B-7	British American Oil Production Co.	5815	6235	6425	7348	7908	8262	8435?	8580	9055	9802	BTD
BE 2	Brock Exploration Corp.	--	--	--	--	--	--	--	--	--	--	--
Choctaw 1												
	Choctaw Oil Co.	5830	BTD									
Hall & Damson 1												
	Brooks Hall & Damson Oil Co.	6455	6758	6963	8240	8640	9288	9522	10048	BTD		

TABLE A-2 (Cont'd)

WELL IDENTIFICATION		Sand No. (	o.	0.	o. 6	Hetero-stegina Limestone	Frio Formation	Mio-gypsina Zone	Cibicides Hazzardi Zone	Marginulina Texana Zone	Bolivina Mexicana Zone	Nodosaria Blanpiedi Zone
State 1												
	Temple Hargrove & Freepor t Suplur co.	5760	6015	6472	7075	7288	7703	8140	BTD			
Texas 1												
	The Texas Co.	6315?	6515	6704	7802	8458	8945	9120	9690	10202?	10970	11445
Texas 2		6149		6485	7340?	8040	8470	?	?	8705	9500?	10220
Texas Levy 1		Fault	6028?	6405	7225	7640	8042	8250	8825	9110	9590?	BTD
Wilbert Minerals Corp.												
F 2	Freeport Sulphur co.	5455?	?	5975	BTD							
F 3		5545	6005	6085	6975	7362	7792	8152	8302	8645	8940	BTD
F 4		5598	5885	6040	6920	7318	7700	BTD				
F 5		5410	5905?	6035	6975	7390	7730?	BTD				
F 6		5522	5788	6210	6973	7298	7648	7830	8192	BTD		
F 7		5585	5855	6300	7230	7608	7860	8020	8378	BTD		
F 8		5588	6146	6275	7210	7602	8045	8315?	8785	BTD		
F 9		5723	?	6200	7180	7695	7965	8155	8360	BTD		
F 10		5518	?	6025	6978	7167	7645	BTD				
F 11			?	5148	6030	BTD						
F 11-I			?	5045?	BTD							
F 13		5785	6054	BTD								
F 13-1		5783	6043	6525	7070?	7340	7775	8130	BTD			
F 14		5548	5886	6250	7002	Fault	7485	BTD				
F 15		5635	5910	6390	6948	7120	7673	8000	BTD			
F 17		5530	5780	6250	6835	6972	7250	BTD				
F 17-1			--	--	6835	?	7362	BTD				
F 18	Freeport Oil co.	5775	6115	6330	7245	7705	7945?	BTD				
F 19	Wilbert State **Unit**	5592	5856	6292	7276	7475	7745	7970	8302	BTD		
F 25-l			?	5605	BTD							
F 28		--	--	5875		7410	BTD					
F 51		--	--	5135?	BTD							
F 53			--	5360	BTD							
F 55		--	--	5485	BTD							
F 60		5278	BTD									

TABLE A-2 (Cont'd)

WELL IDENTIFICATION	Sand 0.	0.	0.	0 6	Hetero-stegina Limestone	Frio Formation	Mio-gypsina Zone	Cibicides Hazzardi Zone	Merginulina Texana Zone	Bolivina Mexicana Zone	Nodosaria Blanpiedi Zone
F 64	--	--	7108	7432	8125	BTD					
F 64-I"	5935	6140	6235	7120	7370	7980	8240	BTD			
F 65	5995	6208	6323	7222	7460	8042	8290	8772?	BTD		
F 76	5060	5555	5955	6645	7057	7495	BTD				
F 78	5585	6160	6295	?	7592	8032	BTD				
F 79	?	?	5705	BTD							
F 81	5802	6086	6553	7598	8096?	8301	BTD				
Wilbert's Myrtle Grovee											
c 14-1	5150?	?	?	6450	6803	7290	BTD				
c 15	4860?	5295	5540?	BTD							
C 16	?	?	?	?	6630	BTD					
Section 58											
Wilbert & Sons **Lumber**											
1 Flaitz & Mitchell	6910	?	7475	8855	9560	10290	10593	11185	BTD		
2	6960	?	7350	8793	9503	10192	10472	10832	11515	11795	12450
Section 60											
Wilbert Minerals Corp.											
F 80 Freeport Oil Co.	6198	6490	6630	7068?	7678	8330	BTD				
PE 1 Precise Exploration Co.	6415	6878	7040	8410?	8825	9548?	9790?	10085	10685	BTD	
Section 61											
Wilbert **Minerals** Corp.											
BE 12 Brock Exploration Corp.											
Cabot 1 Cabot Corp.	6295?	6768	7010	7905	8445?	8850F	9142	9345	9595	9950	BTD
C 18 Carter Oil Co.	6410	Fault	6820	7905	8615	8740	9005	9340?	BTD		
Delta 3 Delta Development Corp.	6172	BTD									

TABLE A-2 (Cont'd)

WELL IDENTIFICATION		Sand 0.	0.	0.	0. 6	Heterostegona Limestone	Frio Formation	Miogypsina Zone	Cibicides Hazzardi Zone	Marginulina Texana Zone	Bolivina Mexicana Zone	Nodosaria Blanpiedi Zone
F 34	Freeport Oil Co.	?	6025	6175F	?	7060	7410	BTD				
F 36		6138	Fault	6396	6990	7148	7845	BTD				
F 57		?	6052	6214	6910	7460	8000	BTD				
F 63		?	6450	6772	BTD							
F 63-1		--	6450	?	7440?	?	8320?	BTD				
F66		5965	6395	6502	7635	8218	8870	BTD				
F77		5986	6302	6498	7478	7872	BTD					
Lone Star 1												
	Lone Star Production Co.	5940	6363	6465	7395	7908	8435	8710	9175	9400	BTD	
LVO 1	LVO Corp.	6563	7098	7250F	8422	9198	9862	10050	10218	10493	BTD	
Texas Pacific												
	Texas Pacific Oil Co.	6586	6901F	7083	8298	9040	9702	9960	10254	10705	10988	BTD
Section 62												
Department of Energy												
DOE 1	Brine Disposal Wells	6680	7188	7403	BTD							
DOE 2		6750	BTD									
DOE 3		6720	7315	BTD								
DOE 4		BTD										
DOE 7		6653	BTD									
DOE 10		6668	7233	BTD								
DOE 12		6668	7242	BTD								

TABLE A-2 (Cont'd)

WELL IDENTIFICATION		Sand 0.	0.	0.	0. 6	Hetero stegina Limestone	Frio Formation	Mio-gypsina Zone	Cibicides Hazzardi Zone	Marginulina Texana Zone	Bolivina Mexicana Zone	Nodosaria Blanpiedi Zone
Township 9 South, Range 12 East												
Section 61												
Gay Union Corp.												
BA 1	Temple Hargrove et al	?	6705	6805	7950	8425	8760	9025	9315	9520	9958	BTD
BA B-l	Temple Hargrove & H. Hurt	6460	6835	6993	8200	8755	9435	9722	10055	10245	10925	11225
c 45	Humble Oil & Refining Co.	Fault	6435	6590	7785	8220	8916	?	?	9205	9990	BTD
C 46		6078	6478	6638	7690	8192	8715	8910	9137	9330	10025	10322
c 47		6070	6252	6417	7565	8002	8425	8650	8890	9060	9630	BTD
C 48		6352	Fault	6543	7656	8155	8675	8880	Fault	9112F	9842	BTD
Davis 1	Davis Oil Co. & Leben Drilling Inc.	6130?	6562	6725	7982	8433	9050	9308	9522	9742	10398	10792
Section 70												
Wilbert Minerals Corp.												
	C. W. Weaver Drilling Co.	6730	7248	7485	8930	9685	10362	10648	11019	--	--	BTD
Section 82												
Wilbert Minerals Corp.												
Delta 2	Delta Development Corp.	6185	6572	6756	7806	8302	8780	8992	9333?	9400?	9980	BTD

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TABLE A-3

DEPTHS TO CAPROCK AND SALT
BAYOU CHOCTAW SPR SITE

NOTES FOR TABLE A-3

1. Depths in Feet
2. Depths written 100/200 refer to the tops of the Clay and Gypsum Zone and Massive Gypsum-Anhydrite Zone, respectively.
3. + before a depth indicates a well not logged to top of salt.
4. + after a depth indicates a well logged from top of salt.
5. DNP - did not penetrate.

TABLE A-3
BAYOU CHOCTAW SPR SITE
DEPTHS TO CAPROCK AND SALT

WELL IDENTIFICATION			CAPROCK	SALT
Township 8 South, Range 11 East				
Section 28				
Morley Cypress				
C	4	Carter Oil Co.	--	7510?
Section 29				
E. B. Schwing				
BA 1		Temple Hargrove et al	--	7831
Township 9 South, Range 11 East				
Section 52				
Gay Union Corporation				
C	1	Standard Oil of Louisiana	1018	--
C	4		--	3212-3428 3630-3645 3714-5594+
C	5		--	4881-5091
C	6		--	4590-5490+
C	8		5796?	6468-6801
C	9		--	6162
C	13		--	9327
C	13-1	Carter Oil Co.	--	9420-9505+
C	14		--	3200-3610
C	18		--	8205-8756+
C	19		--	8105
C	21		--	7776
C	21-2		--	7775
C	26		No	3825-3855+
C	28		No	5194-5490+
C	31		No	4460-4530 4612-4850 4870-5010 5410-5426+
C	36		No	4790-5170 5350-5468+

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TABLE A-3 (Cont'd)

DEPTHS TO CAPROCK AND SALT

WELL IDENTIFICATION		CAPROCK	SALT
Department of Energy			
DOE CH1	(Corehole 1)	516/586	658-809+
DOE CH2	(Corehole 2)	402/509	646-668+
Cavern 2		376/?	639-1846+
Cavern 3		506/625	791-2000+
Cavern 4		?/557	662-1986+
Cavern 8A		437/?	776
Allied 8		450	740
Allied 9		555	890
Cavern 15		415?/525	637-3297+
DOE 15A	(Cavern 15 Re-entry)	485	613-2405+
Cavern 18		420	857-4285
DOE 18A	(Cavern 18 Re-entry)	428/605	805-1816+
Cavern 19		550	850-4440
DOE 19A	(Cavern 19 Re-entry)	565/677	862-2621+
Wilbert Mineral Corp.			
Allied 1	Allied Chemical Corp.	501	655-2300
Allied 5		470	645
Allied 6			
Cavern 7		644	850
Allied 14		535	760
Cavern 16		655	800
Cavern 17		455	660
J1		495/555	645/1132+
N1		525/605	705-1122+
F 16	Freeport Sulphur Co.	1305	1412-2485
F 20	Freeport Oil Co.		4798-4818+
F 22		No	4765-4776+
F 29		No	5447
F 30-1		No	5170-5278+
F 32			4636-4658+
F 35			5415-5468+
F 39		No	4327-4337+
F 40		No	3515-3525 3835-3850 3970-4022+
F 42		No	4060-4106
F 45		503/655	935-2605
F 46		No	3420-4310 4410-4760 5160-5298+

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TABLE A-3 (Cont'd)

DEPTHS TO CAPROCK AND SALT

WELL IDENTIFICATION		CAPROCK	SALT
F 56		No	8415-8424+
F 59		No	1400-1922+
F 59-1		No	1700-1860
F 71		508/715	905/1228
			1258-1342
F 72			1267-1452
			1518-1552
PE 7	Precise Exploration Corp.		2448-4175
C 1	Standard Oil of Louisiana	2535	2566-2710
C 2			4201-5220+
C 3		2438	2469-2472+
C 4		2366-2384+	
C 10	Carter Oil Co.		5235-5303+
C 10-1			4828-4912
C 10-2			4814-4885
			5188-5458
			5494-5814+
C 10-3			5150
C 24		No	3910-4166+
C 25		1790	2010-2113+
C 26		No	4743-4762+
C 27			1290-1910
C 27A		610/710	995-1045
			1295-1880
C 28		No	4735-5000
			5170-5205
			5885-5922+
C 30		No	4868-4893+
C 32		2460-2568	2568-2646
		2732-2775	2774-2829+
C 33		No	4670-4678+
C 38		No	4593-4595+
C 40		No	5275-5395
TGS4	Texas Gulf Sulphur	480-656	
UTP1	Union Texas Petroleum	520	800

Section 53

Department of Energy

Cavern 1		407/579	650-1988+
Cavern 10		?/549	661

TABLE A-3 (Cont'd)

DEPTHS TO CAPROCK AND SALT

WELL IDENTIFICATION		CAPROCK	SALT
Cavern 11		?/605	683
Allied 12		550	920
Cavern 13		571	875
Cavern 20		500	681-4440+
DOE 20A		408/528	692-2438+
Wilbert Mineral Corp.			
F 2	Freeport Sulphur Co.		2273
F 3			9040-9070+
F 11	Freeport Oil Co.	?/560	991-1700
F 12		?/635	940-1640
F 17		850-915	No
F 21		445/545	815-3370
			4270-4669
			5420-5580
F 25		485	754-2220
			2850-2980
F 25-1			+1800-2218
			2850-2980
F 28		375/505	694-3668
			4070-4435
F 51		560/?	793-3155
F 53		635/732	?850-2770
			2852-3000
F 55		?/833	870-2260
F 60		439/482	735-1250
			1395-1600
			2372-2522
F 61		448/510	760-1320
			1948-2085
			2093-2115
			2142-2208
			2355-2375
F 62			+697-2670
			3070-3270
F 69		425/470	670-1238
			1385-1660
			2100-2222
			2335-2500
F 70			2200-2370
			2515-2725
PE 4	Precise Exploration		+980-1745
			2088-2212

TABLE A-3 (Cont'd)

DEPTHS TO CAPROCK AND SALT

WELL IDENTIFICATION		CAPROCK	SALT
Wilberts Myrtle Grove			
C 1	Standard Oil of Louisiana	545	667-2690
C 9		705-1302	
C 11			718-4660
C 12-1			4225-4242+
C 13	Louark Production Co.		852-2894
C 14	Carter Oil Co.		823- 7925-7938
C 15			735-2850
C 16			805-1988
C 29		?/835/1120	DNP
TGS1	Texas Gulf Sulphur		
TGS2			
TGS3		435	660-682+
TGS5		503	690
TGS6		594	679-682+
TGS7			
TGS8			
Section 61			
Wilbert Mineral Corp.			
Delta 3	Delta Development Co.	No	?6940-6991+
F 34	Freeport Oil Co.	No	7885-7903+
F 63		No	7570-7770+

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APPENDIX B

Tangential Sections through the Bayou Choctaw Salt Dome

These additional sections provide details of the salt dome needed to delineate radial faults and correlate the radial sections. Many of these sections are actually parallel or tangential to the salt at the edge of the dome. They complete the three-dimensional picture of the dome necessary for more accurate description of the salt boundaries. These sections should be read in association with the radial sections and plans on top of the various marker beds.

a. Section M-M'

A large-scale section (Figure B-1) tangentially through the "bowtie" structure on the east flank shows this small salt overhang. The overhang runs from southwest to northeast. Steeply-dipping Miocene sands, 4 through 6, overlie the "bowtie" which is cut by the section to show an isolated, dipping salt outlier. The main salt mass is bounded by a tangential fault at a depth of 5400 feet.

b Section N-N'

This section (Figure B-2) runs across the east flank of the dome. It cuts across the even edge of the salt which is completely linear. The structure is simple: active fault F-2 is parallel to the salt on the south side of the section and fault F-4 is parallel to the salt on the north side, but it only extends up to the No. 2 Sand. The shallow structure is a simple doming of sediments over the salt.

c. Section O-O'

The section (Figure B-3) runs northeast-southwest across the southeast corner of the dome. It cuts across domal material including the shale sheath on the south side. Active fault F-2 forms the boundary of this uplift. The northeast side of the dome is paralleled by fault F-9. The shallow structure is a simple faulted doming of sediments over the salt.

d. Section P-P'

This section (Figure B-4) runs east-west across the north flank of the dome. It shows how faults form a simple, even, linear structure. However, the salt and shale sheath at the top of the salt are very complex. The salt is bounded by a deep inner fault parallel to fault F-6 at the west end. The edge of the salt is parallel to fault F-4 at the east end and where there is no clear evidence of a fault. The shallow structure is a complex of faults caused by the salt uplift.

e. Section Q-Q'

The section (Figure B-5) runs northwest-southeast across the northwest corner of the dome. It shows deep salt bounded by fault F-7 on the south. The shallow structure is relatively simple faulting with considerable folding over the salt uplift.

f. Section R-R'

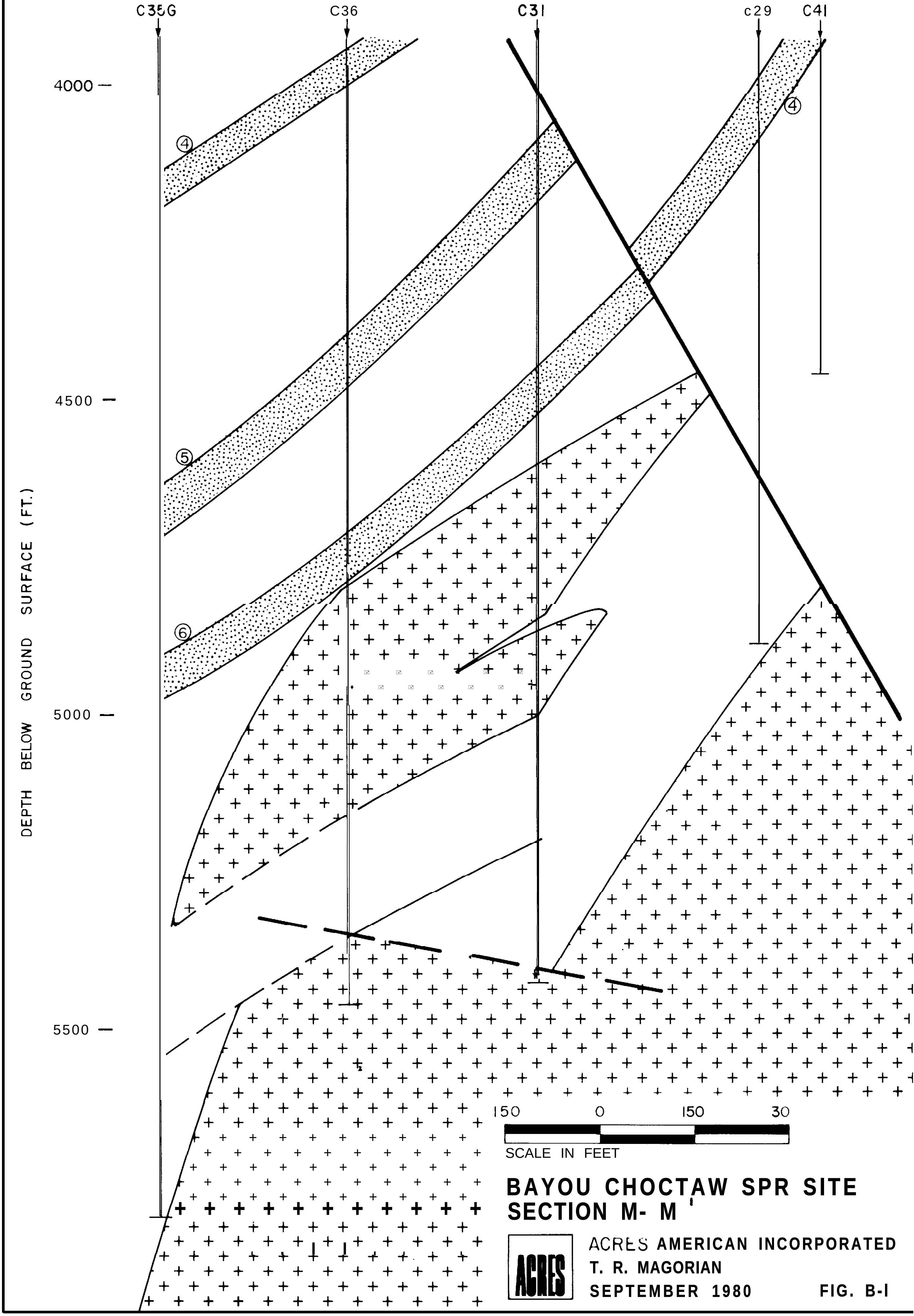
This section (Figure B-6) runs east-west across the north flank of the dome, showing deep salt bounded by simple converging faults carrying an upward wedge of relatively undeformed sediments inside these faults. The shallow structure is a complex of radial and tangential faulting (F-1, F-3 and F-4) over the salt uplift.

g Section S-S'

The section (Figure B-7) runs northeast-southwest across northwest corner of the dome. It shows the north end of the west flank which is bounded by active fault F-1 on the north and F-7 on the south. The shallow, tabular salt intrusive, in the shape of a "sill", is separated from deep salt inferred from surrounding sediments below 6,000 feet.

h Section T-T'

This section (Figure B-8) runs north-south along the west flank, showing the main overhang. The complex base of the overhang follows active faults F-1 and F-2, as well as fault F-6. The section cuts across protruding deeper salt at the center of the west flank bounded at the top by faults F-7 and F-10. The salt forms an hour-glass structure as cut by this section.



BAYOU CHOCTAW SPR SITE
SECTION M- M'

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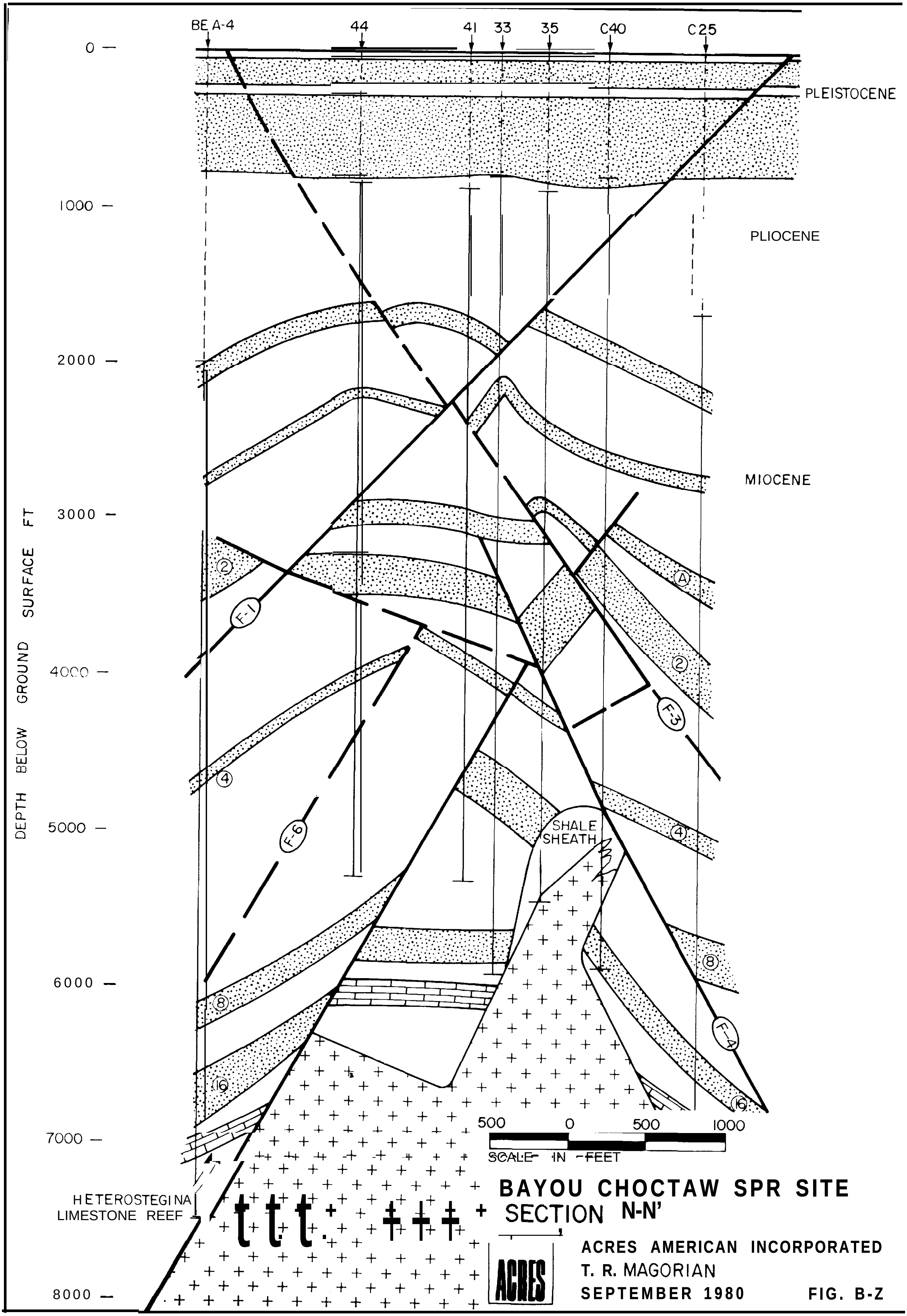
SEPTEMBER 1980

FIG. B-I



BAYOU CHOCTAW SPR SITE
SECTION N-N'

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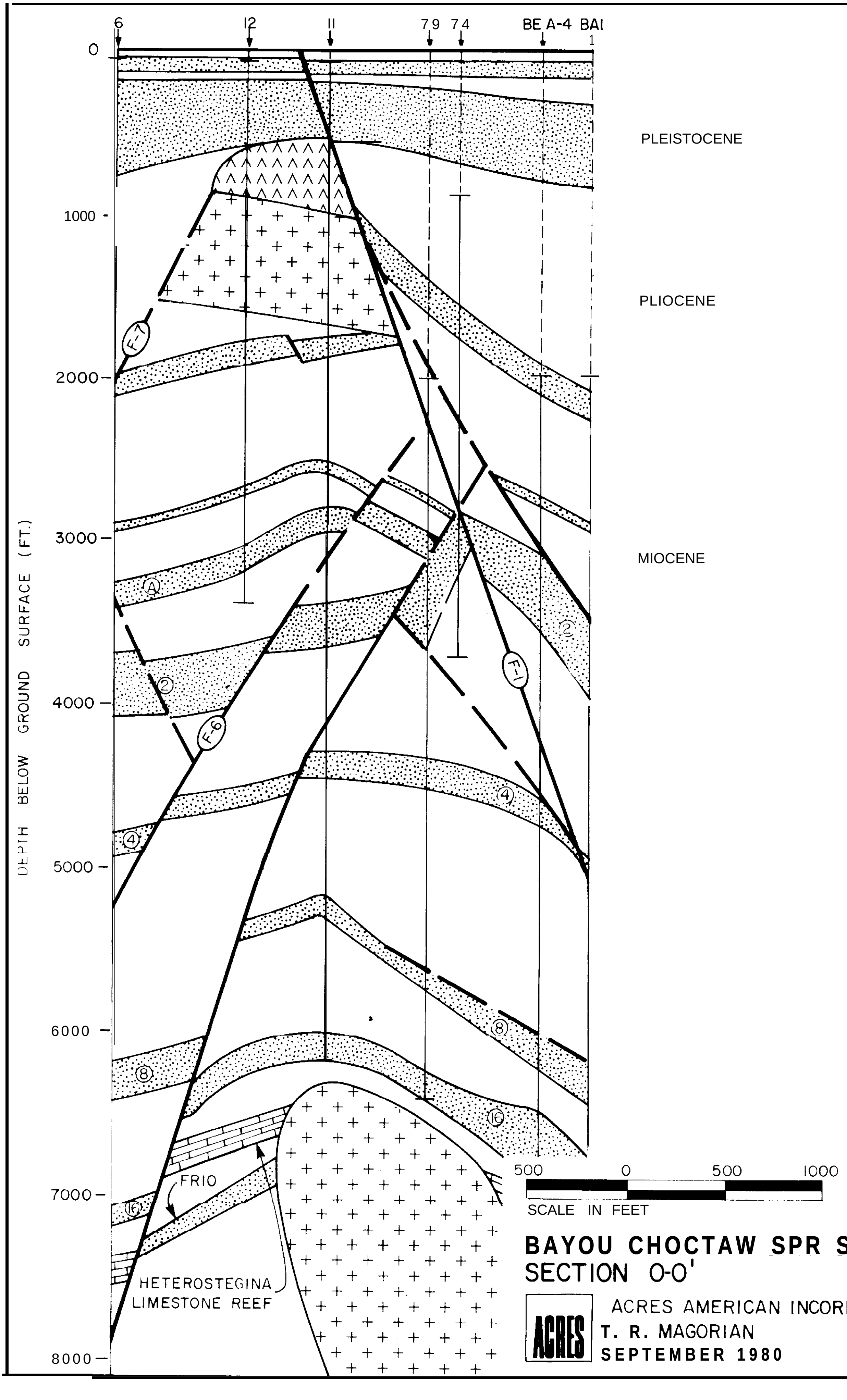
FIG. B-Z



BAYOU CHOCTAW SPR SITE
SECTION O-O'

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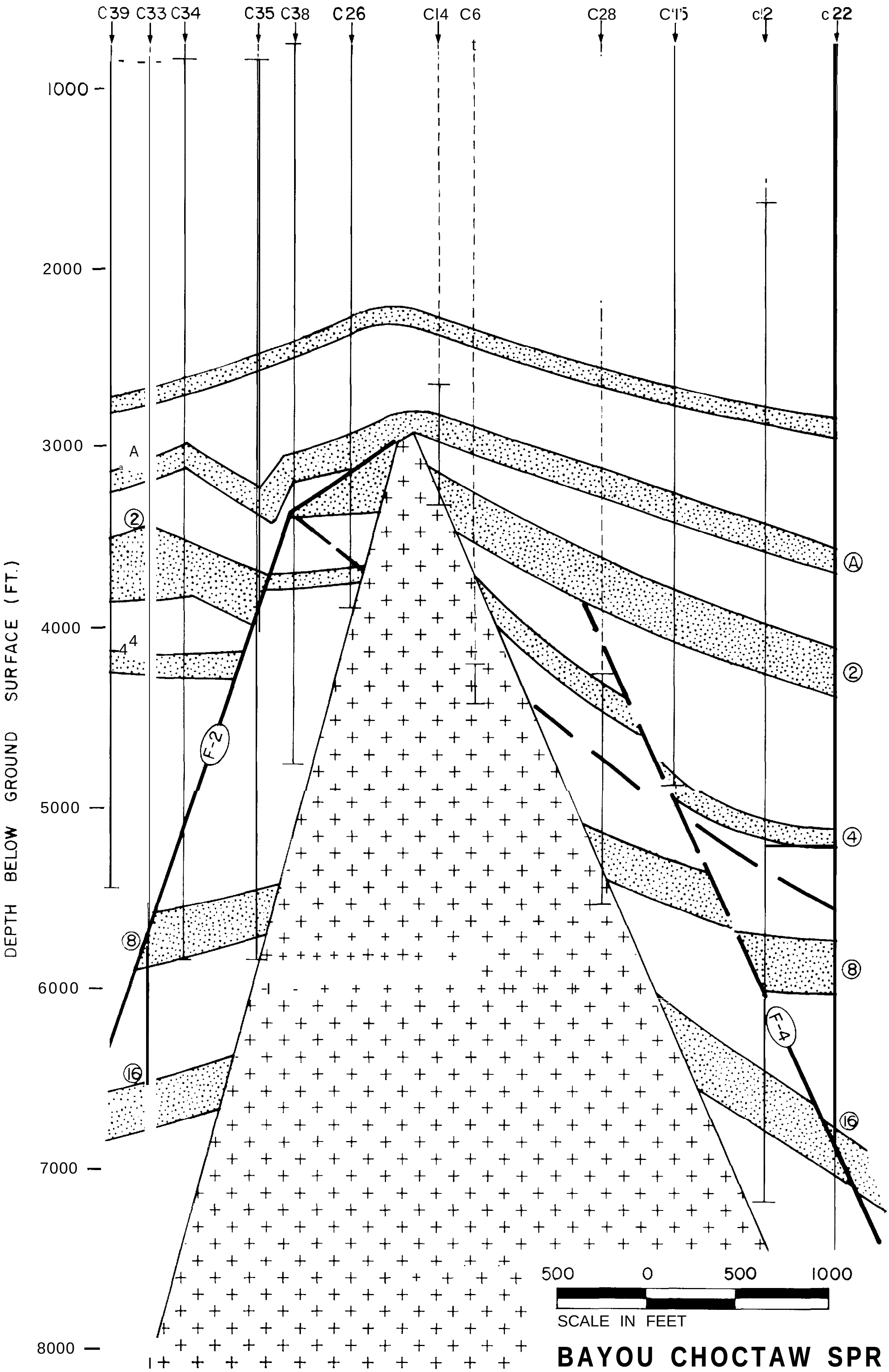
FIG. B-3



BAYOU CHOCTAW SPR SITE
SECTION P-P'

ACRES

ACRES AMERICAN INCORPORATED
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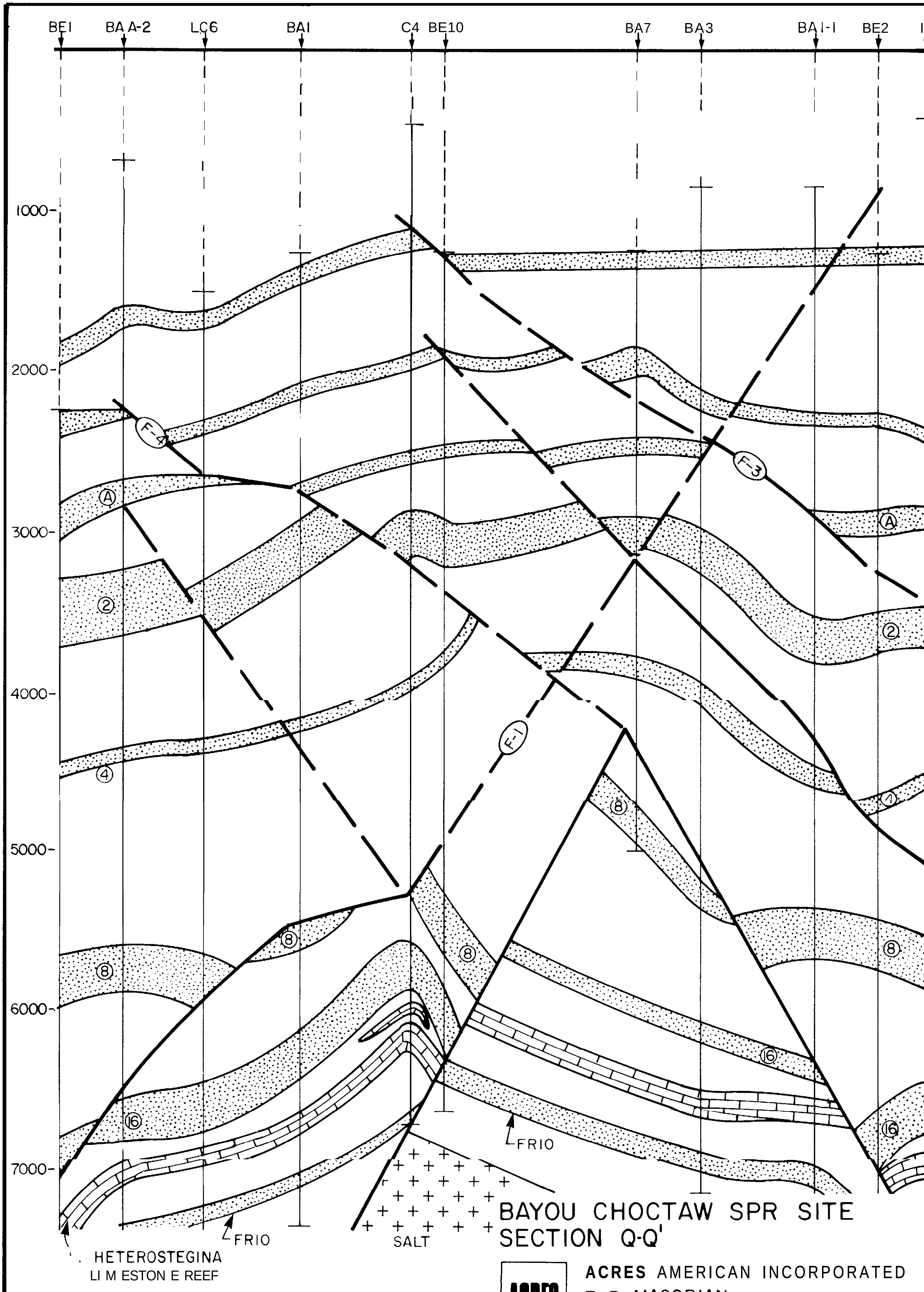
SEPTEMBER 1980 **FIG. B-4**



BAYOU CHOCTAW SPR SITE
SECTION Q-Q'

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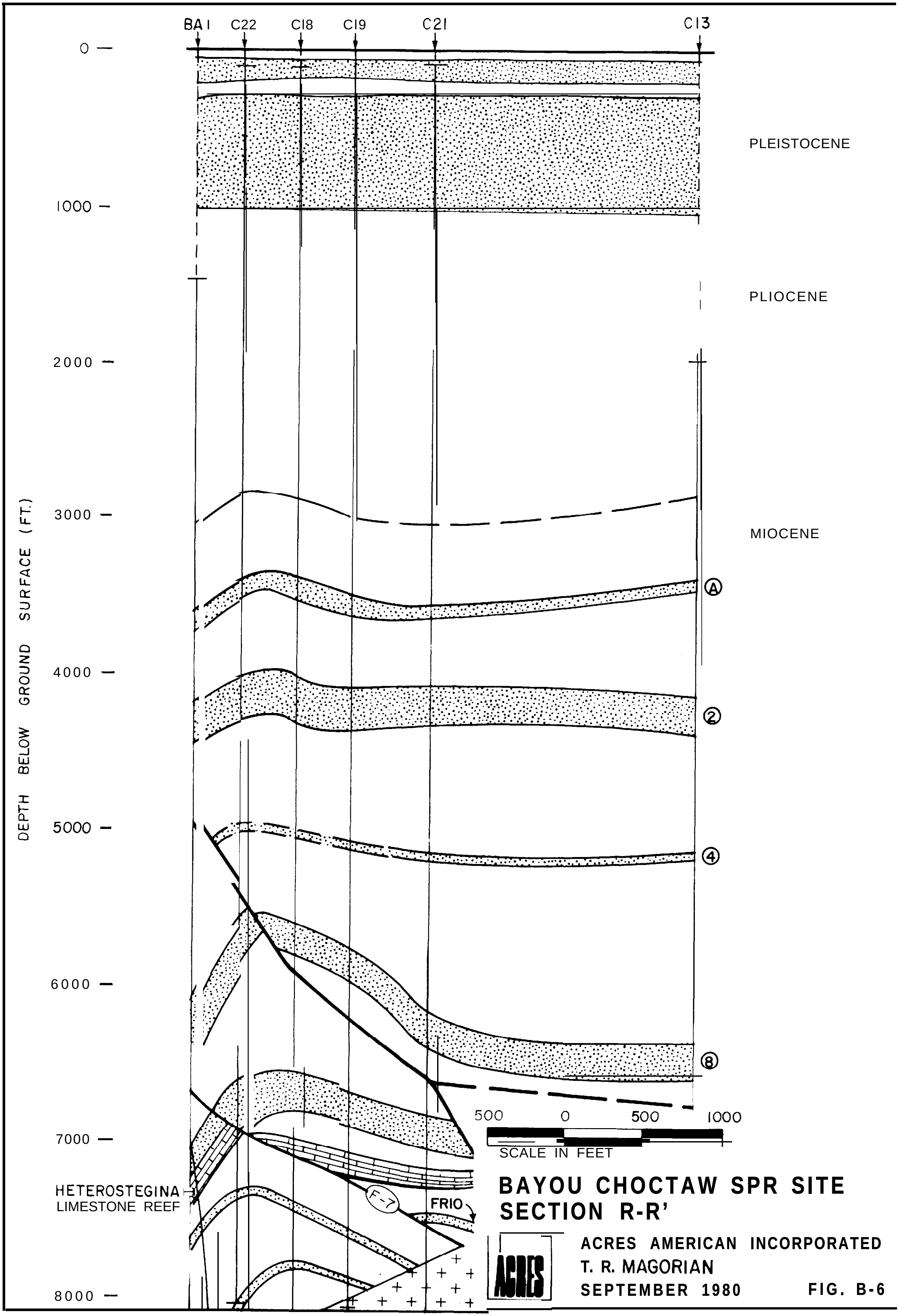
FIG. B-5



BAYOU CHOCTAW SPR SITE
SECTION R-R'

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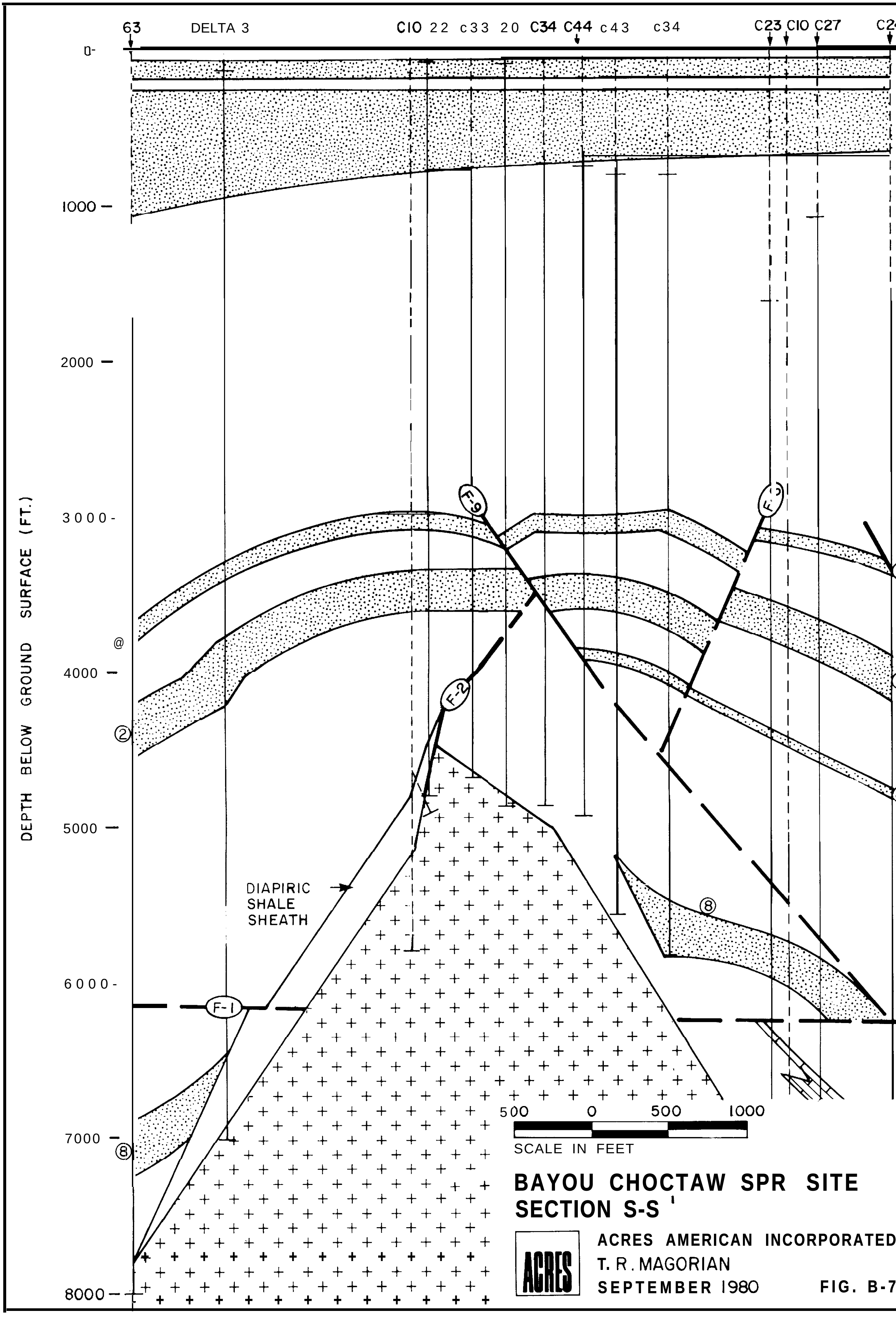
FIG. B-6



BAYOU CHOCTAW SPR SITE
SECTION S-S'

ACRES AMERICAN INCORPORATED
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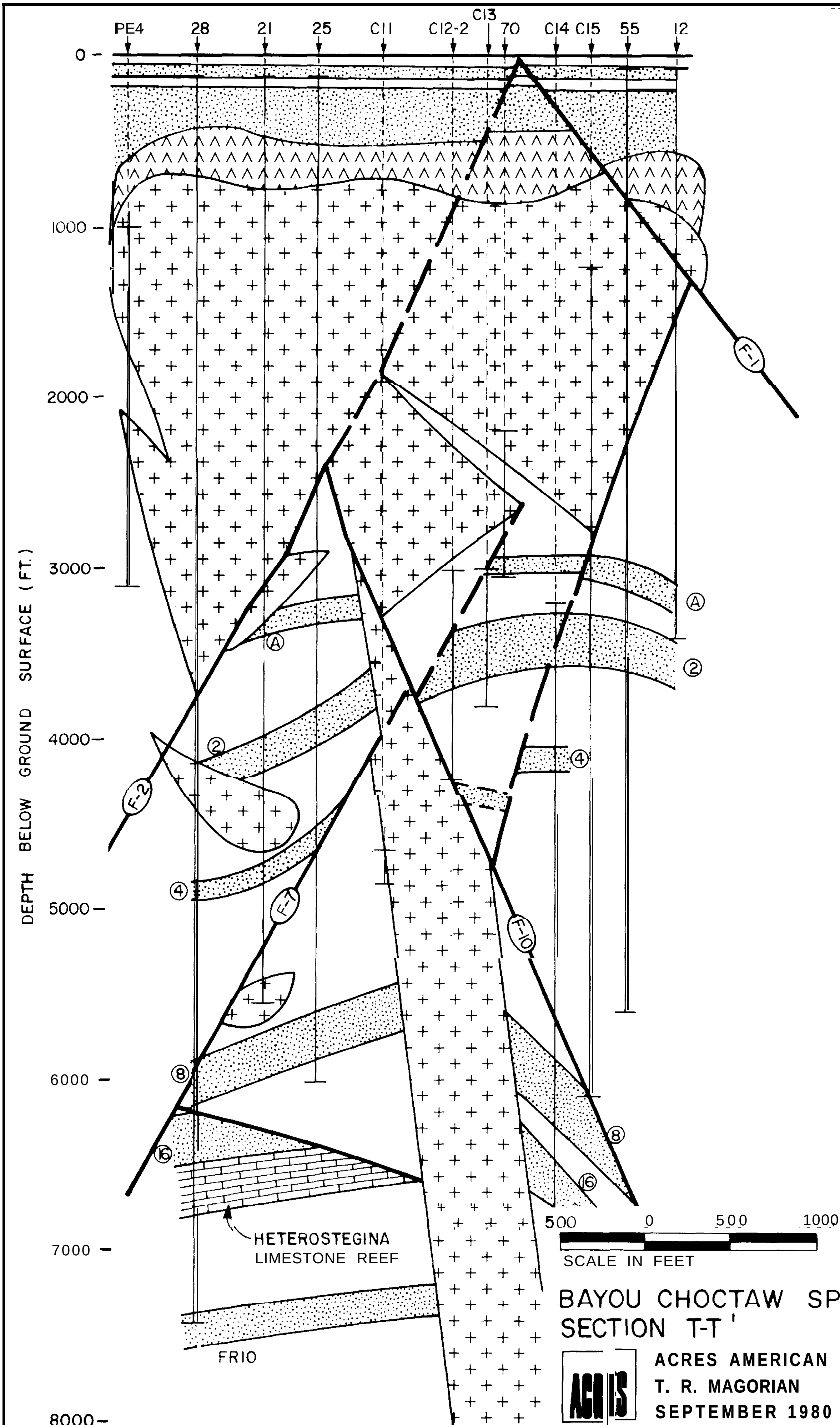
FIG. B-7



BAYOU CHOCTAW SPR **SITE**
SECTION T-T'

ACRES AMERICAN INCORPORATED
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SEPTEMBER 1980 **FIG. B-8**